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ORIGINAL ARTICLES.

I.—On a Neuropterous Insect from the Lower Lias, Barrow-on-Soar, Leicestershire.

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(PLATE V.)

So much attention has been bestowed of late years on fossil organic remains from rocks of all ages, that it must appear surprising to find so little notice has been directed to the Insect-remains from the British Secondary rocks.

It is now nearly fifty years since that veteran geologist, the Rev. P. B. Brodie, M.A., F.G.S., published his modest little 8vo. volume entitled "A History of the Fossil Insects in the Secondary Rocks of England"[1] which is still the only separate work of the kind extant. Numerous Insect-remains have, it is true, been described by Prof. J. O. Westwood, Mr. H. E. Strickland, Prof. J. F. Blake, Mr. A. G. Butler, and Mr. S. H. Scudder, from English rocks of Secondary age; and Mr. Herbert Goss has given an excellent summary of our knowledge of the Mesozoic Insects in the Proceedings of the Geologists' Association (1879).

Although fossil insects are rarely well-preserved in our Secondary rocks, yet it cannot be doubted that they were extremely abundant during this period, their remains having been obtained from the Wealden beds of Hastings. Tunbridge, and Maidstone; the Purbeck beds of Durl'ston Bay, of Swanage, and Ridgway, Dorset, have also long been known to yield such organisms, many of them having been figured and described by Brodie and Westwood; whilst the "Insect-limestone" in the Purbeck strata of the Vale of Wardour in Wiltshire, was formerly the happy hunting ground which furnished the materials for Brodie's History of Fossil Insects. Traces of Insects have likewise been obtained from the Kimmeridge Clay, the Oxford Clay, Forest Marble, Great Oolite, Stonesfield Slate, and lastly from the Lias and Rhætics.

Mr. Herbert Goss, F.G.S.,[2] in his excellent summary of the Insect Fauna of the Secondary Period, writes as follows:—

"The Lias and Rhætic formations are the oldest rocks of this period in which fossil insects have been detected in England. In

[1] London, 8vo. pp. xviii. and 130, with 11 plates, 1845.

[2] See "The Insect Fauna of the Secondary or Mesozoic Period, and the British and Foreign Formations of that Period in which Insect-remains have been detected," by Herbert Goss, F.L.S., F.G.S., Proc. Geologists' Association, 1879, vol. vi. pp. 116–150.

some of the minor divisions insect-remains have been discovered in such abundance that the beds containing them have, as in the 'Purbecks,' been called 'Insect-Limestone.' Fossil insects have been found, chiefly in the lower division of this formation, in Gloucestershire,[1] Worcestershire, Warwickshire, Somersetshire, Dorsetshire, and on the borders of Monmouthshire; a few have also been found in Yorkshire.[2] They are generally in a much more fragmentary condition than those from the 'Purbecks,' and are less common than in the latter formation.

"Mr. Brodie states that he first discovered these interesting fossils in the immediate neighbourhood of Gloucester,[3] and he adds, that some of the beds of limestone in the lowest division of the Lias, in the Vale of Gloucester, abound in insects; and that beautiful specimens, chiefly elytra and wings, have also been found in the Upper Lias at Dumbleton and Alderton.

"At Dumbleton, which is N.E. of Cheltenham, Mr. Brodie obtained from the Upper Lias shales one nearly perfect *Neuropterous* insect, of which Prof. Westwood says[4]: 'It possesses an arrangement of the wing-veins differing from that of any English species, and also from any foreign species known to me, but it comes nearest to the small *Libellulæ* forming the genus *Diplax*.'

"In the Upper and Middle portions of the Lower Lias, which are extensively developed in the neighbourhood of Gloucester and Cheltenham, traces of insects are said to be exceedingly scarce; but at Wainlode Cliff, on the banks of the Severn, near Gloucester, the Insect Limestone has produced remains of several genera of *Coleoptera*. In the Insect-Limestone to the south-west of Combe Hill, not far from the last-mentioned locality, Mr. Brodie obtained a great number and variety of insect-remains, consisting chiefly of the elytra of *Coleoptera*, and a few imperfect but large wings of *Libellulidæ*.

"At Apperley, near Wainlode Cliff, remains of insects have been found in plenty, many small slabs, three or four inches square, exhibiting several elytra and wings, and a few small Beetles.

"From the Insect-Limestone, near the village of Hasfield, Gloucester, many elytra of *Coleoptera* have been obtained. The same formation, in the neighbourhood of Forthampton, near Tewkesbury, has also furnished fossil insects, belonging to the same families as those found in the localities before mentioned.

[1] In a note at p. 378 of the Quart. Journ. Geol. Soc. vol. x. 1854, Prof. Westwood states that "A rich collection of fossil insects, from the Lias of Gloucestershire, etc., has been made by Mr. W. R. Binfield, to whom also the Museum of the Geological Society is indebted for a suite of insects from the Lias of Lyme Regis."

[2] The Rev. J. F. Blake has described and figured two fragments of insects from the Yorkshire Lias. One specimen consists of an elytron of a beetle, named by Mr. Blake *Buprestites bractoides*, and the other specimen consists of two wings of a *Neuropterous* insect, apparently belonging to some species allied to *Chauliodes*, which Mr. Blake has named *Chauliodites minor*. See "Yorkshire Lias," by Ralph Tate and J. F. Blake, London, 1876, p. 426, pl. xvi. figs. 5 and 6.

[3] See Brodie's "Fossil Insects," pp. 51–103, and the Quart. Journ. Geol. Soc. vol. iv. 1846, pp. 14–16.

[4] See Quart. Journ. Geol. Soc. vol. v. 1849, pp. 31–35.

"At Strensham, about nine miles from Evesham, insects have been obtained from a bed of Insect-Limestone at the bottom of a large quarry. Amongst them was found part of the abdomen of a gigantic species of *Libellula*, which Mr. Brodie named *Libellula Hopei*. In the neighbourhood of Evesham the Insect-Limestone has produced numerous remains of insects, the wings and elytra of many of which are said to be beautifully preserved. In the lower division of the Lias, in this neighbourhood, Mr. H. E. Strickland [1] discovered small elytra of *Coleoptera* and portions of the wings of *Libellulidæ*.

"From one quarry near Bidford, Warwickshire, Mr. Brodie obtained a small species of the family *Gryllidæ*, which he named *Gryllus Bucklandi* in honour of Professor Buckland.

"In some of the quarries in this neighbourhood (Bidford) the wings of *Libellulidæ* were obtained, particularly at a place called the 'Nook,' where a beautiful specimen was found, which has been described and figured by Mr. Strickland.[2]

"Mr. E. T. Higgins obtained from the Lower Lias or the Rhætics, in the southern parts of Gloucestershire and the adjoining county of Somerset, in the neighbourhood of Bristol, numerous remains of insects. From Aust, near Bristol, and from Sudbury on the Monmouthshire side of the Severn, about three miles from Chepstow, the Insect-Limestone and the 'Landscape-Stone' have afforded a quantity of remains. In some slabs the insects were found imbedded together in masses. In one slab, Mr. Higgins is stated to have detected as many as 30 small Beetles.

"From the frequency of such delicate creatures as insects in the 'Landscape-Stone,' and in another band of Limestone, only a few feet higher, some of which are said to be beautifully preserved, and could not have been long subject to the action of the waves, it is supposed by Mr. Brodie, that this part of the Lias may have been formed in an estuary, which received the waters of some neighbouring coasts, and which brought down the remains of insects and plants.

"*Coleoptera* appear to have been abundant in the Lias, for out of some 300 specimens, or parts of specimens of insects, obtained from this formation, examined by Professor Westwood, more than one-third were referred by him to this order, and included representatives of the *Buprestidæ*, *Elateridæ*, *Curculionidæ*, *Chrysomelidæ*, *Carabidæ*, *Telephoridæ*, etc. 'Most of the species appear to have been very minute, never equalling in size,' observes Mr. Westwood, 'those from the Stonesfield Slate.' The other orders represented in this formation are the *Orthoptera*, the *Neuroptera*, the *Hemiptera*, and (possibly) the *Diptera*?

"The remains of *Orthoptera* include *Gryllidæ* and *Blattidæ*; the *Hemiptera* include *Cicada* and *Cinneæ*, and the *Neuroptera*, *Libellula*, *Agrion*, *Orthophlebia*, *Hemerobius*, *Æschna*, *Chauliodes* and *Ephemera*. Among these various families and genera we have omnivorous, herbaceous, and predaceous species. Many of the families and genera found in the Lias are common both to it and the Purbecks.

[1] Quart. Journ. Geol. Soc. 1846, vol. iv. pp. 14–16.

[2] See Mag. Nat. Hist. vol. iv. 1840, pp. 301–303, and woodcuts (New Series).

"Although, as a rule, the remains of insects from this formation are very imperfect and fragmentary, the detached wings of many *Neuropterous* insects are preserved in the greatest perfection, and have the nervures of the wings beautifully defined. The size of the insects, judging from the remains, appears to have been usually small and indicative of a temperate climate.

"It may be observed that nearly all the fossil-insects from this formation have, with the exception of a few specimens from the Upper division, been obtained from the *lowest*[1] division of the Lias, or from the Rhætic series, between the Lias and the Trias. Remains of insects from the Lias and Rhætics are very numerous, but the majority of them are in such a fragmentary condition that it has been impossible, even for those who have devoted special attention to the subject, to make out the species to which they belong. About 56 species, however, have been determined, which are distributed amongst five orders as follows, viz.:—*Coleoptera*, 29 species; *Neuroptera*, 12; *Orthoptera*, 7; *Hemiptera*, 6; *Diptera*? 2 (supposed).

"No traces of *Lepidoptera* or *Hymenoptera* have been met with, and the remains which have been referred to the *Diptera* are extremely doubtful."

For permission to describe and figure the very fine impression of a Lias Insect, which forms the subject of Plate V. Fig. 1, I am indebted to the kindness of Montagu Browne, Esq., F.G.S., Curator of the Town Museum, Leicester, who obtained it from the Lower Lias (*Planorbis*-zone), Barrow-on-Soar, Leicestershire, in 1889, when spending his vacation there. The insect is, so far as I am aware, unique of its kind as a fossil, and is preserved in almost equal clearness, as an impression and counterpart, upon two very close-grained slabs of Lower Lias Limestone, from which the well-known hydraulic cement is so largely manufactured. The insect itself is 54 millimetres in length, the fore-legs extending 12 mm. beyond and in front of the head, which is 6 mm. long and $8\frac{1}{2}$ mm. broad. The three divisions of the thorax measure 9 mm. long by $8\frac{1}{2}$ in breadth. The wings, which are neatly folded together, as in repose, are nearly four times as long as they are wide. In addition to two fore-legs already mentioned, one mandible, part of an antenna, the eyes, and the two hind-legs, are more or less perfectly preserved. The wings are clouded with spots of colour such as one frequently sees in these transparent membranous organs in many living *Neuroptera*; such colour-markings have also been figured by Scudder in *Megathentomum pustulatum* from the Coal-measures of Mazon Creek, Illinois, and in his *Brodia priscotincta* from the same horizon, Tipton, Staffordshire.

The tibia and 5-jointed tarsus of the two fore-legs can be very well seen preserved on the slab; the legs are somewhat stouter than in many modern Neuroptera, and the tibia appears to have been slightly serrated or spined, along the inner margin.

[1] Mr. Goss mentions that he had received from the late Mr. Charles Moore, of Bath, a large collection of fossil insects from the *Upper* Lias of Ilminster. This collection included *Coleoptera*, *Neuroptera*, *Orthoptera*, etc.

The head is rounded and of moderate size, with a slight indentation, in front, marking the median line. The mandible, which is serrated, can be seen on the right side, and a portion of the left antenna, with its small bead-like joints, is preserved. The eyes are prominent, but moderate in size. The pronotum is not long and cylindrical as in *Chauliodes*, but is of nearly equal length with the mesonotum and metanotum, but the mesonotum is broadest and is angular in outline. The abdomen is concealed beneath the wings, and its proportions cannot consequently be given.

The wings, in their closed position, measure 42 mm. in length, by 12 mm. in breadth, but being folded upon one another, it is a matter of considerable difficulty to trace the nervures belonging to each of the separate wings. To begin with the anterior border. There is an entire absence of the ladder-like cross-veins which unite the costa with the costal vein in the wings of so many Neuropterous insects; but, apparently, there is a trace of such ladder-like cross-veins to be faintly seen near the distal end of the wings, and *within* their lateral margins, which may possibly belong to the *under*, or hind-wings. With regard to its absence in the upper, or front-wings, it may be explained either (*a*) as not existing; (*b*) as not having been preserved; or (*c*) that the costal margin was folded down out of sight, when the insect was at rest.

(*a*) I do not know of an instance of a Neuropterous insect in which this well-marked marginal line of cross-veins uniting the costal border with the costal-vein, is present in the hind-wings[1] and absent in the front-wings; (*b*) yet it seems unlikely, if it existed, that no trace should have been left along the costal margin in either wing; but (*c*) in a specimen of *Chauliodes Japonicus* (McL.), with the wings closed (which, by the kindness of Mr. Charles O. Waterhouse, I have been enabled to examine, together with numerous other insects, in the Zoological Department), the costal margin of the front wings cannot be seen, being folded down out of sight on each side. I have not seen the living insect; but if this is its normal position when at rest, then it may be that the costal border of the wings of this Lias insect are also concealed in a similar manner beneath the rest of the wing. I do not, however, feel confidence in urging this hypothesis.

After carefully studying the wings and comparing the relative position of the subcostal, the principal, subnodal, median, and subsector veins in recent Neuropterous insects, with the fossil form, I find the points of comparison with *Chauliodes* less satisfactory than I had at first anticipated, and that both in the narrow and elongated form of the wing, as well as its more simple neuration and the absence of the ladder-like cross-veins on the costal margin, there is a greater resemblance to the Termitidæ (sub-order Pseudoneuroptera).

The very distinct evidence of symmetrically-arranged colour-markings and spots on the wings must not, however, be lost sight

[1] As this single line of ladder-like cross-veinlets occurs *within* the wing, it may not after all belong to the margin of the lower or hind-wing, but form part of the cross-veinlets of the front wing itself (as in *Clathrotermes signatus*, Heer).

of, for they closely resemble those observable in many species of Neuroptera (*Chauliodes*, *Neuromus* and *Palpares*), and they do not appear to characterize the wings of *Termites*, which are uniform in colour. Nevertheless, the late Prof. Oswald Heer, in his "Urwelt der Schweiz" (Zurich, 1865) pp. 85–86, taf. vii., has noticed the wing of a fossil insect from the Lias of Schambelen, Switzerland, with an extremely similar venation to our specimen, and,—it is also very interesting to notice,—*with colour-markings* preserved upon its surface. This wing he names *Calotermes maculatus*. He writes as follows:—"At Schambelen six species of *Termites* have been discovered. They agree with the existing species in the general arrangement of the veins of their wings, but differ from them in many other respects; so that they must be regarded as forming peculiar extinct genera, of which I distinguish two. In one of these (*Clathrotermes signatus*, Heer), pl. vii. fig. 8, the costal area of the wing is divided by delicate transverse nervures, into a series of quadrangular cells, and the wings are spotted with black; in the other (*Calotermes*) these transverse nervures are wanting, but the wings are spotted with black in one species (*C. maculatus*, Heer, pl. vii. fig. 7) and Pl. V. Fig. 4. or they have a dark costal area (as in *C. plagiatus*, Heer, pl. vii. fig. 6). These dark spots and bands *are peculiar to the Termites of the Lias*; for all the living species have colourless wings. The Liassic species, like those of the present day, differ much in size; the smallest (*C. troglodytes*, Heer) has wings only $3\frac{1}{3}$ lines long; in the largest (*C. obtectus*, Heer), they attain a length of 9 lines" (English translation by W. S. Dallas, London, 1876).

The new *Termite* from Barrow-on-Soar is relatively so very much larger than any of the remains from the Lias of Switzerland, described and figured by Heer, that it cannot be referred to the same genus, yet it evidently belongs to this peculiar group with spotted wings. Therefore, although I am anxious to avoid the needless multiplication of generic names, I venture to refer our Lias Insect to a new genus, *Palæotermes*, very near to Heer's *Calotermes*, with the distinctive specific name of *Ellisii*, by desire of Mr. Browne, in recognition of his indebtedness to Messrs. Ellis, the owners of the Lias Limestone pits at Barrow-on-Soar, who have, for many years, given him special facilities in the prosecution of his researches.

EXPLANATION OF PLATE V.

Fig. 1*a*. *Palæotermes Ellisii*, H. Woodw., sp. nov. (enlarged twice nat. size); from the Lower Lias (*Planorbis*-zone), Barrow-on-Soar,[1] Leicestershire. One-half is preserved in the British Museum (N. H.), and the other in the Leicester Museum.

Fig. 1*b*. Plan of wing of same, drawn separately, to show probable arrangement of the nervures of the wing. × 2 times.

Fig. 2. Detached wing of *Chauliodes Japonicus*, McL. × 2 times (*ad nat.*).

Fig. 3. Detached wing of *Termes angustatus*. × 2 times (*ad nat.*).

Fig. 4. Detached wing of *Calotermes maculatus*, Heer, from the Lias of Schambelen, Switzerland (copied from Heer's "Urwelt der Schweiz.").

[1] The counterpart of this very beautiful Lias Insect has been kindly presented to the British Museum (Natural History) by Montagu Browne, Esq., F.G.S., who has placed the other half in the Leicester Museum.

II.—The Lamprophyres of the North of England.

By Alfred Harker, M.A., F.G.S.,
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THE north-country lamprophyres occur usually as dykes of no great magnitude, sometimes as sills, more rarely as small bosses or laccolites. They are scattered over an area extending from Teesdale to Furness, from Bassenthwaite to Ingleton. A circle thus defined has a diameter of about fifty miles, and embraces all the known occurrences, though others may exist beyond these limits concealed by post-Silurian strata. In the centre of the circle is the Shap granite, and the probable genetic connexion between the lamprophyres and this granitic intrusion has already been urged by Mr. Marr and the present writer. The chief grounds for such an opinion are as follows:—

(i.) The arrangement of the intrusions, as just noticed, and the radial grouping of the dykes in the central part of the area about the granite.

(ii.) The common age of the intrusions, so far as can be fixed; both granite and lamprophyres being post-Silurian but pre-Carboniferous, and both being connected with the same crust-movements.

(iii.) Certain general chemical relations, to be noticed below; to which may be added some special chemical characters, such as the notable quantity of manganese in the granite and in most of the dykes analysed.

(iv.) The special mineralogical resemblance of many of the dykes to the Shap granite, shown by the occurrence in them of characteristic minerals such as sphene (rarely found in the lamprophyres of other districts), and especially of the well-known porphyritic felspars of the granite. Some of these points are brought out more strongly by comparing the lamprophyres with the dark basic patches so common in the granite.

(v.) The arrangement of the different varieties of lamprophyres, the more basic and characteristic ones occurring especially in the outer parts of the area, the more acid varieties and those having most in common with the granite chiefly in the central tract.[1]

(vi.) The close association with the lamprophyres of acid intrusions of types more normal for apophyses of granites, and the existence of transitional varieties between these acid rocks and the lamprophyres.

Many of the individual rocks have been described by different writers,[2] and it will be sufficient here to recall some of the more significant characters which they have in common. The typical

[1] It may be remarked here that the lamprophyre of Sale Fell, near Bassenthwaite, which is of a somewhat acid variety, may possibly have had a quite distinct origin.

[2] Bonney (analyses by Houghton), Q.J.G.S., vol. xxxv. p. 165; Rutley, *ibid.* vol. xxxiv. p. 29, and Mem. Geol. Surv. Ingleborough (97 S.W.); Tate, Proc. Yorks. Geol. Pol. Soc. vol. ix. p. 372, vol. xi. p. 311, and Rep. Brit. Assoc. for 1890, p. 814; Hatch, *ibid.* p. 813, and Mem. Geol. Surv. Mallerstang (97 N.W.); Balderston, "Naturalist," 1889, p. 131; Harker and Marr, Q.J.G.S., vol. xlvii. p. 285; Harker, *ibid.* p. 521; see also Teall, "Brit. Petr." chap. x.

lamprophyres of the region are exceedingly rich in brown mica, which shows a characteristic mode of alteration by internal bleaching with separation of magnetite or limonite; often also the interposition of little wedges of calcite or dolomite. The mica is often accompanied by augite in well-formed crystals but usually quite decomposed, and in the Sedbergh district Dr. Hatch records pseudomorphs after olivine. Original magnetite may occur in variable quantity, but in very many cases is entirely wanting. Apatite in fine needles is universal. The ground-felspars include both monoclinic and triclinic species, the relative proportions of the two not being a character of importance. In the more altered rocks the felspars are not to be made out at all, unless the carbonates have been dissolved out of the mass. Original quartz occurs in the ground-mass of the lamprophyres in the central part of the area only (the Sale Fell intrusion being excluded).

Certain porphyritic elements enclosed in the general mass of the rocks, despite their insignificant bulk, are of the highest interest: they are quartz and felspars. Quartz is found in some abundance in the intrusions very near the Shap granite; at greater distances it occurs only sparingly and sporadically, but isolated grains are found even in the dykes at Cronkley in Teesdale. In the acid sills and dykes near the granite the mineral forms sharply-defined pyramidal crystals, in the transitional varieties of rock the crystals are more or less rounded, and in the most typical lamprophyres the quartz occurs in rounded blebs rarely showing any relic of crystal outline. The rounding is clearly due to corrosion by the enveloping magma, and the blebs are commonly bordered by a narrow pale-green rim of rather fibrous hornblende, converted in the more decomposed rocks into a chloritoid substance. Isolated quartz-grains with a corrosion-border of augite or hornblende are known in the lamprophyres of other districts, and have usually been regarded as mechanically caught up from the walls of the dyke. Such a view seems to be merely an *à priori* one, based on the improbability of original quartz-grains occurring in basic rocks, and we shall see that the facts are susceptible of a different reading. It may be noted in passing that similar grains of quartz with a corrosion-border of augite are found in various American olivine-basalts, and are clearly shown to be original constituents.[1]

Very similar in many respects are the phenomena of the porphyritic felspars in our rocks. Both orthoclase and oligoclase are found, as in the Shap granite. In the dykes and sills nearest the granite these minerals occur plentifully; elsewhere they are, as a rule, sparingly distributed. In the intrusions in the Cross Fell inlier, for instance, an ordinary hand-specimen may show perhaps one crystal, perhaps none; in Teesdale the felspars are absent, but near Ingleton, at an equal distance from the granite, they occur in some of the dykes. The crystals of both kinds of felspar are always well rounded by corrosion in the typical lamprophyres, less markedly so in the more acid varieties and the transitional rocks, and quite intact in the

[1] Iddings, Amer. Journ. Science, vol. xxxvii. p. 208 (1888).

normal quartz-porphyries. Within a mile of the Shap granite the sills and dykes sometimes enclose large flesh-coloured crystals of orthoclase identical with those in the granite itself, but more or less rounded as in the dark basic patches of the granite. There is, however, a significant difference. The large orthoclase crystals in the dark patches of the granite have a corrosion-border of plagioclase and quartz: in the lamprophyres this feature is not found, but on the other hand the rounded crystals of oligoclase are often bordered with orthoclase. The enveloping magma was in the former case rich in soda, in the latter case rich in potash. It is likely that in other districts special mineralogical relationships exist between lamprophyres and the plutonic masses near which they occur, but unfortunately the rocks have rarely been studied from this point of view. Doss,[1] in describing the lamprophyres of Dresden, remarks that they enclose orthoclase crystals similar to those of the well-known Plauen'schen Grunde syenite, but rounded by corrosion, and these he regards as mechanically caught up from the syenite. Since the dykes which he studied actually traverse that rock, the explanation is of course a possible one, but it does not appear from his description that the crystals have the form of broken fragments, and the case may well be a parallel to that of the Westmoreland rocks.

Having in common the general features outlined above, the north-country lamprophyres still show very considerable variations. The silica-percentage in Mr. Houghton's eight analyses ranges from 60 to less than 40, that of the Shap granite being 69. The figures for the more basic rocks are necessarily unsatisfactory, owing to extreme decomposition, some examples having nearly 30 per cent. of carbonates. The associated acid intrusives and transitional varieties occur well characterized in the centre of the area and to a considerable distance from the granite, but they do not extend so far as the true lamprophyres. They are well developed in the Cross Fell inlier; but some of the acid rocks there are not demonstrably connected with the post-Silurian intrusions, and are possibly Ordovician. In the Sedbergh district the lamprophyres and the acid intrusives are quite distinct, though closely associated, and Mr. Strahan remarks that the former intersect the latter. Rosenbusch makes the same observation in Alsace, and it is probably of some generality. The two sets of rocks, though genetically connected, were derived from different portions of the heterogeneous parent-magma, and the general rule appears to be that the injection of the quartz-porphyries, microgranites, etc., slightly antedated that of the lamprophyres. Where transitional varieties occur, we may suppose either that they were supplied from an intermediate portion of the magma-reservoir, or that an intermixture of the acid and lamprophyric magmas took place during the injection. The striking variability of the rocks in some localities must be due to the latter cause, for in some cases the commingling of the two magmas has been very incomplete. A dyke near Gill Farm exhibits abrupt transitions from quartz-porphyry to lamprophyre, such as admit of no other explanation than

[1] Tsch. Min. Mitth. (2) xi. p. 27 (1890).

that offered. Again, Mr. Houghton's analyses of two rocks from the same locality on Docker Fell show a sharp contrast, their silica-percentages differing by more than 10. Professor Bonney concludes that the two specimens cannot be really from the same dyke, but Mr. Collins in his analyses of Cornish lamprophyres shows an even greater difference between two specimens taken *in situ* from one mass.

A few words on lamprophyres in general will not be out of place at this point. From quite early days such rocks as minette and kersantite have been recognized as interesting types, not very sharply divided from one another, but collectively occupying a position somewhat apart from what may be regarded as more normal igneous rocks. It is true that the principle of classifying rocks by a mere enumeration of their constituent minerals has led some geologists to confuse these types with the mica-bearing syenites and diorites; but such a view is not in harmony with either chemical relationships or geological occurrence. To the field-geologist the rocks in question have always been known as characteristically "dyke-rocks"; more recently they have been shown to occur also as special marginal *facies* of certain deep-seated bodies of rock.

Rosenbusch (1887) distinctly recognizes the individuality of the group, for which he adopts von Gümbel's name lamprophyre.[1] He points out its peculiarities, and separates from the two types already mentioned two others, under the names vosgesite and camptonite, in which the dark mica is more or less replaced by hornblende or augite. He makes, however, a division of the group into a 'syenitic' and a 'dioritic' family, which seems to be quite artificial. It is noteworthy that most of the best known lamprophyres are found in association not with syenites or diorites, but with granites. A glance over Rosenbusch's lists of localities makes this fact at once apparent. In what follows, the lamprophyres will be regarded not as an independent group, but as a special basic modification of rocks of the normal plutonic series. This point of view is scarcely a novel one. Thus we find Hunter and Rosenbusch[2] describing as a new type "monchiquite, a camptonitic dyke-rock associated with the elæolite-syenites" of Brazil and Portugal, while J. F. Williams[3] has given an account of such rocks and others (fourchite and ouachitite) in Arkansas, and has demonstrated their genetic relations with the elæolite-syenites of that state. The varied series of rocks studied by Brögger in the Christiania district seem in several instances to run to lamprophyric modifications, and we may expect much light to be thrown on the subject in that eminent geologist's forthcoming monograph.

In endeavouring to explain the multiplicity of igneous rocks, and the evident genetic relations between widely different types, geologists have been led to speculate on the separation, by gravity or otherwise, of a large reservoir of molten magma into more acid

[1] The name mica-trap evidently cannot be made to cover all the types here included.
[2] Tsch. Min. Mitth. (2) vol. xi. p. 445.
[3] Rep. Geol. Surv. Ark. for 1890, vol. i.

and less acid portions, which, if gravity be the controlling agent, must form upper and lower strata within the reservoir. There can be little doubt that such a hypothesis provides a *vera causa* for many of the phenomena. Now if we compare a more acid with a more basic type in the normal series of igneous rocks, we find certain chemical relations to hold with a high degree of generality. As the silica-percentage diminishes, the proportion of iron-oxides increases (especially at the most basic end of the series), the magnesia increases steadily, the lime increases and then falls off again, the total alkalies diminish, and the proportion of potash to soda also in general diminishes. All systematic treatment of ordinary igneous rocks which is in any degree 'natural' (as opposed to Linnæan) is tacitly based upon these general laws.

We are regarding the lamprophyres as basic modifications of various plutonic rocks, and it is easy to see that tested by the above laws they are abnormal, the exceptional characters being found in the behaviour of the alkalies. This appears on comparing the analysis of a lamprophyre with that of the plutonic rock with which it is certainly or presumably connected. Take, for instance, the biotite-granite of Durbach in the Black Forest, and the remarkable lamprophyre (the durbachite of Sauer[1]) which forms a marginal modification of it. The analyses give—

	Silica.	Soda.	Potash.
Granite	67·70	3·22	5·78
Lamprophyre ...	51·05	1·85	7·24

showing that with a heavy falling off in silica the total of the two alkalies remains closely the same as in the normal rock, while the ratio of potash to soda, instead of diminishing, rises from 1·79 in the granite to 3·91 in the lamprophyre. Again, the quartz-bearing augite-syenite or akerite of Ramnäs passes at its margin into a lamprophyric rock, and the figures are as follows:[2]—

	Silica.	Soda.	Potash.
Akerite	58·48	5·52	3·06
Lamprophyre ...	46·40	4·81	3·84

Here, as before, the total alkalies remain nearly the same, and the ratio of potash to soda increases from 0·56 to 0·80. The augite-minette of the Plauen'schen Grunde may fairly be compared with the syenite which it cuts through, and the results stand thus—

	Silica.	Soda.	Potash.
Syenite	59·83	2·44	6·57
Lamprophyre ...	50·81	1·01	7·01

the total alkalies only falling from 9·01 to 8·02, and the ratio of potash to soda rising from 2·69 to 6·94.

Judged by these examples, the lamprophyres would seem to be special basic modifications of their parent-rocks in which, with a greatly diminished percentage of silica, the total alkalies show little change, while potash becomes more abundant at the expense of soda. We have selected, however, cases of lamprophyres in the

[1] Mitth. Grossherz. Baden Landes, vol. ii. p. 258.

[2] Brögger, *Syenitpegmatitgänge*, p. 49.

closest connexion with their parent-rocks; going to greater distances, we find the total alkalies falling off, but still far in excess of the amounts proper to rocks of like silica-percentage. The relation between the two alkalies noticed above is by no means universally found in the lamprophyres (cf. those of Cornwall), but it is certainly very common and characteristic. The Shap granite has 8·22 per cent. of alkalies. In Mr. Houghton's eight analyses of the dykes the figure varies from 7·99 to 4·52. The ratio of potash to soda in the dykes ranges from 9·51 to 0·93, and is in every case but one higher than the ratio in the granite (1·01). It is particularly high in the most basic of the lamprophyres.

The chemical peculiarity of the lamprophyres, as compared with other rocks of like basicity, consists then in their relatively large content of alkalies, and in particular of potash. The mineralogical peculiarities of the rocks are, of course, simple consequences of this. The abundance of potash enables nearly all the magnesia and iron-oxides in the magma to be built up into brown mica, so that augite and hornblende occur only as minor accessories, and original free iron-ores are in very many cases not formed. A large part of the potash being taken up in the mica, it follows that the predominance of orthoclase or plagioclase among the ground-felspars will not be related in any very simple manner to the proportions of the two alkalies in the bulk-analysis, and a classification of the rocks based on the dominant species of felspar will not be a natural one. Further, in so far as any such relation holds, the plagioclase-rocks will, broadly speaking, be more acid than the orthoclase-rocks derived from a similar parent-magma. It may be noticed in the analyses of the typical European rocks that the kersantites are more acid than the minettes. Another consequence of the abundance of the basic silicate mica in the ordinary lamprophyres is that free quartz is often formed in rocks with not much more than 50 per cent. of silica.

If the more ordinary types of lamprophyres are to be regarded as specialized *facies* of granites and syenites—the conclusion to which the foregoing remarks tend—it may be asked whether other families of plutonic rocks may have like modifications connected with them. A few peculiar rocks have been described which might possibly be considered in such a light. I would doubtfully instance Koch's[1] olivine-mica rock forming a small dyke in Kaltenthal in the gabbro-district of Harzburg. This may be compared with the immediately adjacent gabbro of Ettersberg, analysed by Streng, as being conceivably a lamprophyre (in the extended sense) of that rock, thus:—

	Silica.	Soda.	Potash.
Gabbro	50·09	1·39	0·83
Lamprophyre?...	34·98	0·17	5·42

Here the large quantity of potash in the second rock is very striking. In the other constituents the relation of the rock in question to the gabbro is that of an ordinary ultrabasic to a basic type.

Returning to the rocks of the North of England, the question naturally arises: how did the lamprophyric magma become ab-

[1] Zeits. deuts. geol. Ges. vol. xli. p. 163 (1889).

normally enriched in potash as compared with ordinary basic segregations? On this point some suggestions may be offered. We may imagine beneath the area where the lamprophyres are now exposed, or beneath the central part of it, a deep-seated reservoir of molten magma which was partially separated under the action of gravity, the heavier basic portion forming the lower strata. In this magma, as it cooled, the earlier products of consolidation crystallized out, the most important of these early products being the large crystals of orthoclase. It is a known fact that felspar-crystals will sink even in a basic rock-magma, and thus as the crystals formed, they must have accumulated at the bottom of the reservoir, and thus modified the total composition of the lower basic strata. The examination of the Shap granite proves that a certain portion of the quartz, the sphene, and especially the apatite crystallized out before or simultaneously with the large felspars, and these too would sink to the bottom. The felspars and quartz have been dissolved by the basic magma, but their elements would not be redistributed through the whole magma in the reservoir, except in so far as the dissolution of the crystals was concurrent with their accumulation. The process of solution seems to belong to a later stage, that of a relief of pressure when the injection of the dykes took place. Since the porphyritic felspars occur plentifully in the Shap granite, we must suppose that their sinking to the bottom was finally arrested by a general consolidation of the magma, or at least a certain degree of viscosity in any part which remained molten. Subsequently to this came a partial refusion of the whole and the intrusion of the granite into its present position, closely followed by the injection of the acid dykes and sills and almost immediately the lamprophyres. The diminutive size of the corroded felspars in the latter rocks probably indicates that many others have been entirely dissolved in the containing magma, and this solution is most reasonably referred to the epoch of the injection of the dykes. It corresponds to the "resorption" phenomena in the intratelluric hornblende and biotite of many andesites, etc., effects ascribed to the relief of pressure in the process of extravasation of the lavas. Felspar-crystals, as has been stated, are found, though as a rule sparingly, in some lamprophyres at a considerable distance from the centre of the area; but, in view of the narrowness of many of the dykes, it seems probable that their transportation has been in some measure checked by a sifting or filtering action.

The above considerations may appear very speculative; but in reality, if the magma-reservoir be granted, they scarcely go beyond known facts. If some such hypothesis be found satisfactory in the area considered, it may possibly have a wider application. Certainly the association of mica-lamprophyres with porphyritic granites in numerous districts is rather striking. The porphyritic felspars, however, must not be regarded as essential. All that is requisite is that some constituent rich in alkali should crystallize out at an early stage in a magma more or less separated under the action of gravity. Such constituent may be in different cases a felspar, a

felspathoid (leucite, sodalite, etc.), or a mica, and there may or may not be any undissolved relics of it in the lamprophyre as finally consolidated.

One other remark may be made in conclusion. In rocks containing abnormally large proportions of potash and soda, and having at the same time plenty of alumina, it should not be surprising to find occasionally minerals richer in alkali than the felspars. Now at Cronkley, on the banks of the Tees, all the dykes contain a mineral which in thin slices shows hexagonal or quadrangular outlines, with a dark border and nucleus. The sections have no very definite action on polarized light, and seem to be more or less completely converted into obscure decomposition-products. Mr. Rutley regarded the mineral as decomposed garnet, but if it occurred in a phonolite or leucitophyre it would probably be put down confidently as nosean. Without expressing an opinion on this point, I will observe that in the most easterly dyke, where the mineral in question is most abundant, there occurs another with square contour, bright blue colour, and single refraction, which I can refer to nothing but haüyne.

III.—An Improved Method of taking Impressions of Fossils, etc.

By J. G. Goodchild, F.G.S.

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Palæontologists and others concerned with fossils often have need of some method of taking impressions of fossils, which shall at the same time be simple and efficacious, and shall also be of such a nature as not to cause injury of any kind to the original. Many different processes have been tried, with varied success. The following method has stood the test of application to a wide range of subjects, and has answered its purpose well in the hands of a considerable number of workers:—

The only outfit required is a small roll of thin tinfoil of ordinary quality, a small plate-brush, neither too hard nor too soft, a bottle of shellac varnish, and some paraffine wax, with a night light or some such means for melting it.

If the fossil is not in too high relief, say a fossil fish, or such a plant as a Coal-measure fern, all that is needed is to cut a piece of foil rather larger than the specimen, then to press it gently, with the finger tips at first, into all the larger depressions, beginning at the middle and working outwards towards the edge all round. Then, keeping the fingers extended over the impression, go over the whole thing with the plate-brush, using it as gently as possible, and with only a very slight lateral movement. After a few seconds treatment of this kind an almost exact counterfeit of the fossil will appear—even some of the very finest sculpturings being distinctly visible on the upper surface of the foil.

When that stage is reached, the foil should be lifted very gently at each corner so as to free it from any projecting or undercut points. Herein lies the special value of the tinfoil process, inasmuch as this material does not enter the undercut parts as modelling wax,

gutta percha, etc., are apt to do; consequently when the tinfoil is withdrawn it never drags away part of the fossil. When the foil is loosened so that it will lift off easily, it should be gently pressed back again with the brush so as to make it resume its proper shape. Then, if the subject is tolerably flat, and no holes have been torn in the foil, it may be lifted off at once. To fix it, the most important part of the process, it will generally suffice to pour on to the impressed, or under, side, sufficient shellac varnish (which should be of a consistence between that of cream and that of treacle) to float the whole surface. This should not be distributed by means of a brush, but by simply turning the impression about until the surface is covered by the varnish. In a few minutes this will be dry enough to lay by. A second coating, later on, will render it quite hard enough to stand ordinary handling without any risk of altering its shape.

Should the fossil be in somewhat higher relief, so that a few holes are torn in the foil, the best mode of treatment is to go over the upper surface of the "counterfeit" with a thin coat of melted paraffine while it is on the original. The wax chills at once into a firm mass, and the foil may be lifted off with ease. Then the back is floated with varnish as before. When this is set, all that is necessary to do is to put the foil into water sufficiently hot to melt the paraffine, which at once floats off, leaving the foil quite bright, as before.

In the case of objects in very high relief more care is, of course, required; but the process answers very well even then. Thanks to the courtesy of Dr. Traquair, I have been enabled to make tinfoil counterfeits of a large number of fossils from the collection in the Edinburgh Museum of Science and Art, many of them in high relief, by this process; and, with a little management, have been able to make them retain the form of the original perfectly, by coating the inside of the impression with cotton-wool, and flooding this with varnish as before.

In some respects impressions made by this process are even better than the originals; for the metallic lustre of the tinfoil causes the light to be reflected from the salient parts of the copies much more strongly than from the originals. Indeed, when the part of the foil representing the matrix is painted a dead black, I find it much easier to draw from the foil impressions than from the originals.

Another advantage presented by this method is that any number of copies can be made in a very short space of time; and in lecturing on Palæontology in Edinburgh, I am able in the majority of cases to place in the hands of each student a reliable copy of the fossil I am describing, and in this way he is able to make more satisfactory progress than would otherwise be possible.

Lastly, as Curator of a Collection embracing nearly twenty thousand specimens of fossils, I am occasionally called upon to lend out specimens for description. In all such cases my plan is to take a careful tinfoil counterfeit of the original before it goes out, and this, with the register entry, places the exact nature of the loan on record in a manner that leaves nothing to be desired.

IV.—On the Nature and Origin of Earthquake-Sounds.

By Charles Davison, M.A.;
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THE sound-phenomena accompanying earthquakes have not often been made the subject of special investigation; and, consequently, their value and significance may have been somewhat underrated. I believe that much remains to be done, that many observations must yet be made, before the problem of their origin can be regarded as completely solved; but the facts already known seem to me sufficient to show that the inquiry is one full of interest and worthy of development beyond that here attempted.

Nature of Earthquake-Sounds.

1. *Character of the Sound.*—The sound is sometimes of so unusual a character that it is difficult to describe it exactly, but generally it more or less resembles one of the following: (1) *Thunder*—either a clap or a prolonged peal, the rolling of distant thunder, or thunder when it dies away as echoes among mountains. (2) *The rumbling of passing carriages, wagons, etc.*—driven rapidly over a hard road, over pavement, stones, a wooden or stone bridge, or under a gateway, a heavy traction-engine passing, a couch or heavy chair dragged across the floor of a room above, a train rapidly approaching or rushing through a station, the jerking of a train brought suddenly to rest, the rumbling of wagons laden with planks, stones, or heavy casks. (3) *The firing of cannon*—either one or several in quick succession, a heavy and well-sustained fire of artillery, a distant cannonade. (4) *An explosion*—a blast in a quarry, a colliery explosion, the blowing-up of a magazine or powder-mine. (5) *The fall of heavy bodies*—a cartload of stones suddenly emptied, a heap of rubbish shot down, a large quantity of shingle poured on to a house-roof from a great height, the fall of houses, snow sliding down the roof of a house and falling on the ground, an avalanche of snow, the fall of heavy furniture, a signal-post or a heavy mattrass, a cannon-ball rolling downstairs. (6) *Wind*—a blast or sudden gust, the roar of wind in a storm, wind among trees, the suppressed roaring of wind entering a gorge, a chimney on fire. (7) *Miscellaneous*—a hissing noise like that of red-hot iron plunged into water, the rushing of water, the cracking of a wall, a door violently slammed, the breaking of glass, a horse loose in its stall, the muffled rat-a-plan of heavy side-drums, a burst of applause in a room overhead like what newspapers call "loud and prolonged cheering."[1]

In a few cases (the breaking of glass, for example, or the rustling

[1] This list, by no means an exhaustive one, is compiled from 389 accounts, obtained from the third part of Mallet's Catalogue of Recorded Earthquakes (Brit. Assoc. Rep. 1854), Meldola and White's East Anglian Earthquake of 1884, and the notes communicated to me by correspondents during my study of the British earthquakes of the last three years. Out of the above number, comparisons are made to thunder in 97 cases, to the passing of carriages, etc., in 130, the firing of cannon in 53, explosions in 45, the fall of heavy bodies in 33, wind in 27, and to various sounds under the last heading in 14 cases.

of wind among trees), the sound is a comparatively high one; but, most frequently, it is *a deep rumbling noise, sometimes perhaps not very much above the lower limit of audibility.*

2. *Variations in Intensity and Pitch.*—The frequent use of the words "rolling" and "rumbling" in describing earthquake-sounds, as well as comparisons to thunder, etc., shows that the sounds do vary both in intensity and pitch.

On a few rare occasions, the sound is said to begin or end abruptly, the intensity being at, or not far from, its maximum. But most frequently, almost invariably I believe when the observation is complete, *the sound begins faintly, becomes continually louder, and then gradually dies away.* As might be expected, this change in intensity is most marked in the immediate neighbourhood of the epicentrum; near the limits of the sound-area it is hardly perceptible, and the sound there resembles closely the low roll of distant thunder.

Records of variation in pitch are far from numerous. The following may be given as examples: (1) 1791, Nov. 27, Lisbon. Two shocks, one five minutes after the other. The second and more violent shock "was attended with a hissing noise like that of red-hot iron quenched in water, and ended with an explosion like the report of cannon."[1] (2) 1884, April 22, Essex. At Summerhill, about 1½ miles N.W. of Colchester, "suddenly a jingling noise was heard, which developed rapidly into a deep underground rolling noise." The beginning of the sound seems to have preceded the beginning of the shock, and, at two other places in the neighbourhood, this was the case.[2] (3) 1890, Nov. 15, Beauly, near Inverness. "There was a great noise, as if huge quantities of shingle were being poured upon the house-roof from a considerable height, the sound deepening to that of heavy artillery." The evidence is too scanty to support any certain conclusion, but it seems to afford some grounds for believing that *the sound becomes deeper as it increases in intensity*; in other words, that the period of vibration increases with the amplitude.

Relations of the Sound to the Shock.

1. *With regard to Time.*—Professor Milne, in an interesting "Note on the Sound Phenomena of Earthquakes,"[3] remarks that in the majority of cases, the sound precedes the shock rather than follows it; and he conjectures that the sound, when it does follow the shock, may be an independent phenomenon.[4]

In order to determine the relative frequency of the different cases, I examined the accounts given in the third part of Mallet's "Catalogue of Recorded Earthquakes" (*i.e.* those occurring between August 26, 1784, and the end of 1842), in which the time-relation

[1] Mallet, Catalogue of Recorded Earthquakes, Brit. Assoc. Rep. 1850, p. 30.
[2] Meldola and White, East Anglian Earthquake of 1884, pp. 55, 57, 58.
[3] Japan Seismol. Soc. Trans. vol. xii. pp. 53–62.
[4] There can be no doubt that this is frequently the case. See, for instance, M. Boussingault's paper, "Sur les détonations constatées pendant les tremblements de terre," Comptes Rendus (July 18, 1881), vol. 93, pp. 105–6; also Humboldt's Cosmos (Bohn's edition), vol. i. pp. 203–4.

of the sound to the shock is definitely stated. There are in all 423 records. The sound is said to have

Preceded the shock in	100 cases.
Accompanied or attended it in	307 ,,
Followed it in	9 ,,
Preceded and accompanied it in	2 ,,
Accompanied and followed it in	2 ,,
Preceded, accompanied and followed it in	3 ,,

It must be admitted that the phrase "accompanied" or "attended," singly, is a very vague one. As a general rule, it only means that the sound was heard at about the same time that the shock was felt; hardly ever, perhaps, that the beginning and end of both sound and shock were coincident. It cannot, then, be taken to exclude cases in which the sound may have overlapped the shock at either end or both. The meaning of the terms "preceded" and "followed" is less ambiguous, though not free from doubt. But, so far as regards the earthquakes recorded by Mallet, it is clear that the beginning of the sound must have preceded that of the sensible shock much more frequently than the end of the sound followed that of the shock.

Turning, however, from these earthquakes, which are, as a rule, of considerable intensity, to shocks of slight intensity and short duration—shocks, for example, like those generally felt in this country—it will be found that the comparative rarity of subsequent sounds is not so strongly marked. In studying the Inverness earthquake of November 15, 1890, I received definite replies to the question on the time-relations of the shock and sound from 64 places, with the following results.[1] The sound is said to have

Preceded the shock at	20 places.
Accompanied it at	26 ,,
Followed it at	1 ,,
Preceded and accompanied it at	5 ,,
Accompanied and followed it at	5 ,,
Preceded, accompanied and followed it at... ...	7 ,,

In the other British earthquakes which I have studied the observations on this point are less numerous, but they are sufficient to show that, in certain parts of the disturbed area at any rate, the sound frequently continues to be heard after the close of the sensible shock.

2. *With regard to the Maximum Intensity of the Shock and Sound.*—It has been already remarked that, in British earthquakes, the sound increases in intensity, to a maximum, and then dies away. Now, it appears, from a large number of observations, that *it is just at the moment when the sound is loudest that the principal vibrations are felt.*

This fact was noticed fifty years ago by Mr. David Milne (afterwards Milne-Home) in a valuable series of papers on the earthquakes of this country. In summarizing their principal features, he remarks that there appear to be two distinct sensations, a tremor and a violent blow or concussion, the latter known in Comrie and the neighbourhood as the "thud." "The tremulous or trembling motion," he says,

[1] Quart. Journ. Geol. Soc. 1891, p. 623.

'is always perceived. When the blow occurs it is generally in the midst of the tremors, and at the moment that they are the most intense, and accompanied with the loudest noise."[1]

In studying the more recent British earthquakes, I have received many observations on this point, of which the following examples may be given: (1) The epicentrum of the Kintyre earthquake of July 24, 1890, was a few miles from Clachan: at which place the shock began with a series of slight tremors lasting for twenty seconds. These tremors gradually "increased in intensity until a vibration was felt like what would be caused by a heavy stone falling from a very great height," and this vibration, again, was followed by tremors lasting for five seconds. During the whole time of the tremulous motion a sound was heard like the crashing of falling stones, and, coincidently with the principal vibration, a dull "thud" as of a suppressed explosion.[2] (2) In nine different accounts of the Inverness earthquake of November 15, 1890, a similar phenomenon was described. At Boleskine, for instance, an observer "heard a sound as if a heavy train was approaching, ... it gradually got louder and louder until it seemed to go right through the house, shaking the pictures and china ornaments on the walls." (3) Still more to the point, perhaps, is a remark made by an observer at Boscastle (Cornwall) of the earthquake felt there on March 26, 1891. This earthquake consisted of two distinct shocks separated by an interval of a few seconds. The sound was loudest just at the times when the shocks were felt, and continued, though more faintly, during the whole of the interval between them.

A. Relations of the Sound to the Disturbed Area.

1. *Variations in the Nature of the Sound and in its Relation to the Shock throughout the Disturbed Area.*—In every earthquake, of which sufficiently numerous observations have been made, the sounds vary greatly throughout the disturbed area, not only in intensity, but also in character, duration and relation to the shock.

In the great Neapolitan earthquake of 1857, so ably studied by the late Mr. Mallet, the sounds were heard over an area roughly elliptical in form, its longer axis being directed about N.W. and S.E. All the observers towards the northern and southern extremities of this area described the sound as "a low, grating, heavy, sighing rush, of twenty to sixty seconds in duration, some thinking that it was also a sort of rumbling sound, but with none, a distinct, well-defined explosion, or several in succession." Those "who were situated towards the middle of the sound-area, and towards its east and west boundaries, on the contrary, very generally described the sound, as something of the same character as to *tone*, but with more rumbling . . . . and as shorter and more abrupt both in commencement and ending, and in duration."[3]

The Inverness earthquake of November 15, 1890, was, I believe,

[1] Edinburgh New Phil. Journ. (1841), vol. xxxi. p. 261.
[2] Geol. Mag. (1891), Vol. VIII. pp. 453–4.
[3] 'The Neapolitan Earthquake of 1857,' vol. ii. p. 288.

caused by the slip of a fault running approximately north-east and south-west, and hading to the north-west, the slip extending probably over a horizontal distance of several miles, and being greatest towards the south-west. Now, "the 25 places at which the sound preceded, or preceded and accompanied, the shock, though not confined to any one part of the disturbed area, are mostly situated in the district north-east of the epicentrum," while five of the six places at which the sound followed, or accompanied and followed, the shock are "either south-west of the epicentrum, or close to it on the north-west side, *i.e.* just where the intensity is greatest."

2. *The Extent of the Sound-area is independent of that of the Disturbed Area.*—Humboldt, in his "Cosmos," remarks that "the intensity of the hollow noise which generally accompanies an earthquake does not increase in the same degree as the force of the oscillations;"[1] and it has also been observed that, in very violent earthquakes, the sounds are confined to a comparatively small area in the neighbourhood of the epicentrum. The Neapolitan earthquake of 1857, for instance, disturbed the whole of the Italian peninsula south of lat. 42°, being felt nearly as far as Rome, while the sounds were only heard within an area containing 3300 square miles immediately surrounding the epicentrum.

The slighter shocks of this country also afford good examples. In the East Cornwall earthquake of October 7, 1889, and the Inverness earthquake of November 15, 1890, the sounds were heard at nearly all the places where the shocks were felt; though it is of course possible that in these cases the coincidence of the sound-area and the disturbed area may have been apparent rather than real. The Edinburgh earthquake of January 18, 1889, disturbed an elliptical area, about 30 miles from north to south, and 26½ miles from east to west; the length of the sound-area was about 25 miles from north to south, its breadth could not be exactly determined. The disturbed area of the Lancashire earthquake of February 10, 1889, was approximately circular, being 56 miles from north to south and 54 miles from east to west; the sound-area was very nearly circular and 29 miles in diameter.

These examples are sufficient to show that the extent of the sound-area bears no constant relation to that of the disturbed area. As a general rule, we may say that, the more intense the earthquake, the less is the ratio of the extent of the sound-area to that of the disturbed area; but this is by no means always true.

The limiting case, in which sounds are heard without any perceptible shock, is one of which records are frequent. One of the most remarkable is that described by Humboldt in his "Cosmos," where he refers to the subterranean thunderings (*bramidos y truenos subterraneos*) of Guanaxuato on the Mexican plateau. "The noise," he says, "began about midnight, on the 9th of January, 1784, and continued for a month. . . . . From the 13th to the 16th of January, it seemed to the inhabitants as if heavy clouds lay beneath their feet from which issued alternate slow rolling sounds and short

[1] Vol. i. p. 203.

quick claps of thunder. The noise abated as gradually as it had begun. It was limited to a small space, and was not heard in a basaltic district at the distance of a few miles." "Neither on the surface of the earth," he adds, "nor in mines 1600 feet in depth was the slightest shock to be perceived."[1]

The following accounts throw additional light on the subject: (1) At East Haddam, Conn., U.S.A., on May 16, 1791, at 8 p.m., two shocks were felt in quick succession, of which the first was the more violent. Soon after, these were followed by a third and slighter shock, and this, again, by nearly one hundred feebler shocks throughout the night. "Subterranean noises are constantly heard at East Haddam, whence its Indian name, Morehemodus, or the place of noises. After this shock, both noises and shocks became less frequent." In several cases noises were heard about this time unaccompanied by any shock. (2) In Piedmont, on April 2, 1808, at 5.43 p.m., an earthquake of intensity VIII., according to the Rossi-Forel scale, was felt, its centre of disturbance having apparently been at Pignerol. This was followed by a large number of slighter shocks (Mallet records about 300) until July, 1809, after which they became less frequent. At Barga, La Tour and other places in the district, subterranean noises were often heard without any accompanying shock. (3) In the island of Meleda, in the Adriatic, noises were heard during a still longer period, from March, 1822, to February, 1825. Mallet remarks that they "do not seem to have been accompanied by any true earthquake shocks, or, at least, any such felt were extremely slight;" but, according to Humboldt, they were "occasionally accompanied by shocks." (4) At St. Jean-de-Maurienne (in Savoy) and the surrounding district, 49 principal shocks were felt between October 4 and December 28, 1839, "and many more indistinct ones which were not recorded. . . . . They were generally preceded or accompanied by subterranean noise, and sometimes this noise was heard without any sensible shock." (5) On October 3, 1839, a remarkable series of shocks commenced at Comrie, in Perthshire. "The shocks were in general very slight, but sometimes rather severe, and were generally accompanied by subterranean noises, variously described as like distant thunder, the reports of artillery, the sound of a rushing wind, etc. The noise . . . . was often heard without any sensible shock at the time." It would appear from these examples that *subterranean sounds without any accompanying earthquake especially characterise those districts where slight shocks are very frequently felt*, as if the sounds and shocks were manifestations, differing only in degree and the method in which we perceive them, of one and the same class of phenomena.[2]

[1] Vol. i. p. 205–6.

[2] Mallet's Catalogue of Recorded Earthquakes, Brit. Assoc. Rep. 1854, pp. 28, 31, 68–84, 138, 152, 162, 166, 288, 290; Humboldt's Cosmos, vol. i. p. 205, footnote. Possibly also of seismic origin are the phenomena known as the Barisúl Guns, "sounds resembling the fire of heavy cannon at a distance, which are heard at various points in the Delta of the Ganges and Brahmaputra, and in the hills to the north of it" (Brit. Assoc. Rep. 1891).

On the other hand, there is the well-known instance mentioned by Humboldt, of no sounds at all being heard during a very violent earthquake. "I have ascertained with certainty," he says, "that the great shock of the earthquake of Riobamba (4th February, 1797) —one of the most fearful phenomena recorded in the physical history of our planet—was not accompanied by any noise whatever;" and again, later on, speaking of the same shock, he says: "The earthquake itself was neither accompanied nor announced by any subterranean noise."[1] This is the only example I know of, and it is obvious that a satisfactory theory of earthquake-sounds must account for the commonness of the one extreme case and the rarity of the other.

B. 3. *The Sound-area is not necessarily concentric with the Disturbed Area.* — The excentricity of the sound-area is one of the most important phenomena connected with earthquake-sounds, and it was the recognition of this in the cases of the Edinburgh and Lancashire earthquakes of 1889 that led to the theory explained in the latter part of this paper. I will here give a short outline of the principal facts, referring for a fuller description of the sound and other phenomena of these shocks to my paper, "On the British Earthquakes of 1889."[2]

Edinburgh earthquake of January 18, 1889.—The epicentrum is situated about 3 miles W. 42° S. of Balerno, and the centre of the sound-area about $2\frac{1}{2}$ miles to the south or south-east of the epicentrum. Both points lie on the north-west or downthrow side of the first of the great faults to the north-west of the axis of the Pentlands; and it is very probable that the earthquake was due to the impulsive friction arising from a slight slip of this fault at a spot not far from the middle of its course as laid down upon the Survey map, a slip which increased the throw of the fault. The centre of intensity of the seismic focus was probably at a point on the fault at the depth of about eight miles. The simple character and short duration of the earthquake show that the horizontal length of the area over which the slip took place was not great, perhaps not more than a mile. Now, the centre of the sound-area is close to the line where the fault meets the surface, nearer to it by about $2\frac{1}{2}$ miles than the epicentrum; and this shows that *the sound-vibrations must have chiefly proceeded from a part of the focus nearer the surface than did the vibrations of larger amplitude which caused the shock itself.*

Lancashire earthquake of February 10, 1889.—The epicentrum of this earthquake is about two miles N.N.E. of Bolton, and on the north-east or downthrow side of the great Irwell valley fault. About $3\frac{1}{4}$ miles S.S.W. of the epicentrum, and apparently at a short

[1] Cosmos, vol. i. p. 203, and vol. v. p. 172. Mallet, in his Catalogue, occasionally indicates an earthquake as having been unaccompanied by sound, but it is not certain that his observations were drawn from a large part of the disturbed area. Prof. Milne states that sounds are not often heard during the Japanese earthquakes, but many of these earthquakes originate under the sea, and the places where they are observed in Japan may possibly be outside the sound-areas.

[2] Geol. Mag. (1891), Decade III. Vol. VIII. pp. 57, 306, 364, and 450.

distance on the upthrow side of the same fault, is the centre of the sound-area; but its position cannot be determined with any great accuracy, for I know of no places where the sound was certainly not heard. The evidence obtained is, I believe, sufficient to show that the earthquake was caused by a slip of the fault referred to, the slip being one that increased its throw; that the centre of intensity of the seismic focus was at a depth of about $3\frac{3}{4}$ miles; that the horizontal length of the area over which the slip took place was short, perhaps less than a mile. Remembering the uncertainty in the position of the centre of the sound-area, I think we may infer that, in this earthquake also, the sound-vibrations originated at a part of the fault nearer the surface than the centre of the seismic focus.

C. Origin of Earthquake-Sounds.

Within the last few years, the numerous seismographic records made in Japan by Profs. Milne, Ewing and Sekiya have thrown considerable light on the nature of earthquake-vibrations. It is chiefly, however, that part of the series including, and bordering on, the sensible vibrations which has been studied: for, as Prof. Milne remarks, "many earthquakes, like the solar spectrum, have extremities which are difficult to investigate."

The records referred to show that earthquakes usually begin with a series of very small and very rapid tremors, from six to eight occurring every second; that, after lasting perhaps for many seconds, they become less rapid, and then, without any break of continuity, follow the sensible vibrations of larger amplitude and longer period, at the rate of about three to five per second. One or more of these, attaining an amplitude still greater and having a period of one or two seconds each, constitute what are generally known as the principal shock or shocks. The earthquake closes with vibrations of smaller amplitude, but "which are so long in period, that the pointers and steady points of our seismographs do not give a relative movement, but follow these back and forth movements as a whole, and no record is obtained." On the other hand, they fail to register the commencing tremors of the earthquake on account of their extremely small amplitude.

Now, for the part of the series preceding and including the principal shocks, the period of the vibrations increases with the amplitude; and it is therefore not unreasonable to conclude, as Prof. Milne has done, that the first tremors recorded are "the continuation of still smaller and more rapid movements, which on account of want of sufficient multiplication in our instruments have never yet been rendered visible." And it is to these supposed very rapid vibrations, which form the front portion of an advancing earthquake, that Prof. Milne attributes the origin of the earthquake-sounds. Summing up, he says: "The majority of earthquake-sounds are produced by short period surface vibrations of the earth and these vibrations are portions of and continuous with the earthquake that accompanies the sound." [1]

[1] Japan Seismal Soc. Trans. vol. xii. pp. 107 and 60.

Throughout the remainder of this paper, I shall conclude that Prof. Milne's observations do, as he suggests, imply the existence of preliminary vibrations short enough in period to give rise to the phenomena of earthquake-sounds; and I shall endeavour now to show how these vibrations originate, and at the same time to account thereby for the different sound-phenomena described above.

To give definiteness to the theory, I shall take the case of an earthquake produced, as I believe most non-volcanic earthquakes are produced, by the friction due to the slipping across one another of the two rock-surfaces of a fault.

The seismic focus, or slip-area, may be of very considerable dimensions, sometimes fifty miles or more in length. The intensity of a shock does not, however, depend so much on the size of a slip-area as on the maximum amount and short duration of the slip. Now, it is evident that the amount of the slip must vary greatly throughout the slip-area, but it will be sufficient to consider only the simplest case, that in which the amount of slip is a maximum in a certain central region, and diminishes gradually until it is zero along the margin of the seismic focus; though the faces of a fault not being smooth planes, there will probably be several or many such regions of maximum slip.[1]

Now, since up to a certain point the period of a vibration increases with its amplitude, and since the initial amplitude of the vibrations must depend on the amount of slip producing them, there will, from all parts of the slip-area considered, proceed vibrations varying, not only in amplitude, but also in period; and along the borders of the slip-area, where the fault-slip dies away, these vibrations may be small enough, and consequently rapid enough, to produce the sensation of sound. I imagine, then, that *the sound-phenomena accompanying earthquakes are produced by the minute vibrations coming chiefly from the upper and lateral margins of the slip-area.*

For brevity, I will give the name of the "sound-focus" to that part of the slip-area or seismic focus from which the sound-vibrations come.

The boundary-line between the sound-focus and the rest of the seismic focus is not a definite line. Its position varies with the lower limit of audibility of each observer, so that at exactly the same spot two observers might differently estimate the duration of the sound. But, neglecting for our present purpose this personal equation in the observers, it is evident that the position of the boundary-line referred to depends only on the position of the points on the slip-area at which the amount of slip is just small enough to produce vibrations which may be heard, that it is independent of the maximum amount of slip within the seismic focus. Now, other conditions being the same, the dimensions of the sound-area are determined by the intensity of the vibrations which are just perceptible as sound, and those of the disturbed area by the maximum

[1] The rumbling or rolling character of the sound, though arising partly no doubt from interference, may also in part be due to the existence of several regions of maximum slip.

intensity of the initial earthquake-vibrations; and therefore *the extent of the sound-area must be independent of that of the disturbed area.*

It is possible that from the lower margin of the slip-area sound-vibrations may proceed; but, so far as regards the sounds heard at the surface, the vibrations proceeding from the upper and lateral margins must be most perceptible. The centre of intensity of the sound-focus must therefore, as a rule, be within the upper margin of the seismic focus, i.e. *the sound-area is not concentric with the disturbed area, and the centre of the former is nearer to the fault-line than the centre of the latter.*

Throughout the greater part of the sound-area, the vibrations first perceived must be those from the upper or lateral margin of the seismic focus, i.e. *the beginning of the sound must generally precede the beginning of the shock.* There will, however, be a small part of the disturbed area, that immediately surrounding the point where the normal to the slip-area meets the surface, where the shock may be felt first: unless, indeed, the fault-slip does not take place instantaneously, but, commencing very slowly, initiates a series of short-period vibrations from the whole slip-area before the true earthquake vibrations are produced. In this case, however, the excentricity of the sound-area would be hardly perceptible.

At most places within the sound-area, then, the sound will be first heard, due to vibrations proceeding from the nearer lateral margin of the seismic focus. The sound will become gradually louder and deeper until its intensity is a maximum, the vibrations then coming from the boundary-line between the sound-focus and the rest of the seismic focus. Soon after this, the sensible shock will be felt, due to vibrations proceeding from that part of the focus where the amount of slip is greatest, the sound continuing for all or part of the time, owing to the arrival of vibrations from the upper margin of the slip-area. And, lastly, after the sensible shock ceases to be felt, will be heard the sound coming from the further lateral margin of the slip-area, provided that margin be not too distant, the sound becoming higher as it dies away.

In the neighbourhood of the boundary of the sound-area, the sound-vibrations from the further lateral margin of the seismic focus will be imperceptible, and the sound will be heard only preceding, or preceding and accompanying, the shock; and this may in part account for the comparative rarity of the records of the subsequent sound-phenomena.

Again, in most British shocks, the part of the focus from which the sensible vibrations come is of small magnitude, so that *only one or two principal vibrations are produced, and these are felt just at the time when the sound is loudest.*

If the sound-vibrations first or last perceived be those which come from the boundary between the sound-focus and the rest of the seismic focus, the sound will begin or end abruptly. But observations of such a phenomenon must be rare.

The different relations between the dimensions of the sound-area

and the disturbed area may be attributed to variations in the amount of slip throughout the seismic focus. (1) If the amount of slip be everywhere very small, the sound-focus may occupy the whole of the slip-area, and thus sound may be the only phenomenon perceptible at the surface to the unaided senses. This seems to have been frequently the case amongst the series of small slips which produced the numerous slight shocks at Comrie, Pignerol, and elsewhere. (2) If the sound-focus occupy nearly the whole of the slip-area, the amount of slip in the rest of it being small, but still great enough to produce a slight shock, then the sound-area and the disturbed area might be approximately co-extensive, or the sound-area might in places entirely overlap the disturbed area. (3) But very frequently, especially in the more pronounced seismic areas, the maximum amount of slip within the seismic focus will be so great that the disturbed area will be large compared with the sound-area, and, in severe earthquakes, will extend far beyond it. (4) Lastly, the slip might take place suddenly, and its amount be so great, that the sound-focus might be confined to the lateral margins of the slip-area. The slip would then extend up to the surface of the earth, and, if great enough, might be traceable there as a difference of elevation on the two sides of the fault-line; the sound-area would consist of two detached portions at some distance from the region of maximum disturbance, and the sounds consequently might escape observation and record.

But while earthquakes of such extreme intensity are very unusual, very slight slips must frequently take place; so that earthquake-sounds without an accompanying shock should be of far more common occurrence than earthquakes without attendant sounds.

V.—Notes on the Ash-slates and other Rocks of the Lake District.

By W. Maynard Hutchings, Esq.

(*Concluded from page* 161.)

TAKING the other and coarser constituents of such slates as are not wholly made up of the fine "base,"—the constituents which may be spoken of as "porphyritic,"—the *lapilli* vary very greatly in number and distinctness. In a large part of the roofing-slates they are either no longer discernible at all or are so exceedingly faded and blurred as to be just barely recognizable, often as patches altered to chlorite, or chlorite and calcite, in which the felspar-laths of the original andesitic ground-mass may still be seen comparatively little altered. In cases where there is reason to suppose that the lapilli were largely of more *basic* nature, this almost complete alteration of them is observed, as might naturally be expected.

In other cases the crushing and rolling-out of the rock has sufficed to obliterate all traces of original fragments of whatever sort. On the other hand, there are many slates in which lapilli, in great abundance, are still so perfectly preserved as to exceed in freshness

most of the andesites, etc., which can be collected *in situ*. Even in some cases where the slates are most highly cleaved, and the "base" and some of the other constituents, as chlorite and calcite, are drawn into streaks often flowing round the still angular lapilli, these latter have almost wholly escaped mechanical damage. In these cases of strikingly good preservation basic lapilli are absent. The slates from Mosedale quarry have already been mentioned as offering beautiful examples of well-preserved lapilli, and equally good ones are seen at other places.

It is to be noted that though rhyolite is exposed in comparatively few localities in the district, it is more or less represented in almost every specimen of slate in which the lapilli are still distinct. This frequent occurrence of rhyolite in the fragmental rocks of the Lake District has been noticed also by Harker and Marr (On the Shap Granite, etc., Quart. Journ. Geol. Soc. vol. xlvii. 1891).

In addition to volcanic lapilli, many of the slates and tuffs show also the presence of fragments of sedimentary rocks, presumably broken through and ejected by the explosive eruptions. I have formerly recorded (Geol. Mag. 1891, p. 462) the occurrence of such a mixed volcanic and sedimentary material in a tuff at Falcon Crag. It may be observed again, though in less marked degree, in rocks from Honister Crag, both roofing-slates and coarser tuffs and breccias, in which fragments of grits and gritty slates occur; and in material from several other localities careful search shows that fragments of ordinary sedimentary slates are present, recognizable, among other things, by the rutile-needles contained in them. In many cases these fragments are crushed and drawn out so as to be almost incorporated beyond recognition with the volcanic material, and it is most likely that, as might be expected, a large proportion of the ashes and tuffs of the district contain more or less of the sedimentary strata underlying them.

Angular clastic grains of quartz, some of good size, are also tolerably frequent, suggesting a derivation from some coarse-grained acid rock, probably granite.

None of the finer-grained slates, so far as my observations go, contain any trace of augite or other ferro-magnesian mineral. These are now represented entirely by chlorite, calcite, and some epidote. Chlorite is always present in large quantity in the coarser slates, as patches and rolled-out streaks, as well as in the minutely-felted form in the base. Calcite is exceedingly abundant, disseminated as small grains down to fine dust, or as larger grains and crystals. These frequently contain fluid-cavities with bubbles, showing the conditions of pressure, etc., under which this calcite was deposited. In many slates the calcite is so plentiful that it very nearly obliterates everything else except the chlorite, the rolled-out mixture of the two appearing at first sight to make up nearly the entire rock.

It is interesting to note that though the mineral changes which have taken place in the finely-powdered ash-material of these slates are in a most important point similar to those which have occurred in the deposits to which we owe our fireclays and shales and most

of our sedimentary slates, inasmuch as a very large amount of new mica has been formed, yet in the matter of the titanic acid contained in the material acted upon the result is very different.

It is beyond question that the volcanic rocks of the Lake District contain a quite considerable amount of titanic acid, though it has not been determined in the analyses made.[1]

Probably a portion was combined in the form of sphene, but most likely the greater part was contained in the augitic minerals. In the weathered and much altered andesites as we now have them, *secondary* sphene is one of the most constant constituents, in granular form and also as little clusters and groups of crystals, often evenly disseminated throughout the rock. This sphene has probably been mainly formed during the decay of the augites and the basic portion of the ground-masses. At Shap, under the influence of contact-action, the sphene of the andesites and ashes appears to have been re-dissolved and re-deposited, one of the most striking features of the altered rocks being the considerable number of large grains of deep-coloured, very dichroic sphene which have been formed, wholly different from anything seen in the rocks at a distance from the contact. Sometimes these large grains of sphene occur in cavities in such relationship to quartz and other infiltrated matter as to leave no room for doubt as to the manner of their deposition.

Notwithstanding this considerable amount of titanic acid, however, the slates resulting from the chemical and mechanical alteration of the andesitic ashes do not ever show the rutile-needles so universally characteristic of the sedimentary clays and slates. From a considerable observation of these rocks from all over the district I am able to state that rutile in that form is never noticed in them, except in those cases in which it is explained by included sedimentary matter originally containing it. To the best of my belief, based on much study of this special point, it may be pretty safely said that rutile in the form we know as "slate-needles,"—a form so very characteristic and always recognizable,—occurs only as the result of decomposition, under certain conditions, of deposits partially consisting of biotite. As I have noted in a former paper (Geol.

[1] Even now that the general presence of titanic acid in rocks is more fully known than formerly, it is very rarely determined by analysts. This arises to some extent from the fact that its non-determination does not affect the total addition of the analysis, as in the ordinary course of the estimations it is weighed partly with the silica and partly with some of the bases. But the non-determination is more largely due to the fact that the exact quantitative serparation of titanic acid is a very tedious and difficult operation.

In the "American Journal of Science" for December, 1891, is an interesting paper by Mr. F. P. Dunnington, "On the Distribution of Titanic Oxide upon the Surface of the Earth," in which he gives the results of 72 determinations on soils from various parts of the world, as well as on a few rocks. The universal diffusion of this oxide in appreciable quantity is fully demonstrated. These many determinations were not made by Mr. Dunnington in the ordinary tedious gravimetric manner, but by a rapid calorimetric process which is described in the paper. It is to be supposed that this method has been fully checked and proved to be reliable. That being so, the determination of titanic acid in our rocks and minerals ought to become the rule instead of the exception, since an easy and rapid method is available for it.

Mag. 1891, p. 537), biotite appears to be practically absent from the rocks of the Borrowdale series.[1]

The titanic acid in these slates takes other forms. It largely occurs, as in the altered andesites, as disseminated granules and small crystals of secondary sphene. Slates showing this, to the exclusion of any other form of occurrence, are exemplified in the quarries at the top of Kentmere Valley, and on the other side of the same ridge in Troutbeck Valley.

Rutile occurs, though on the whole sparingly, in the form of blunt crystals and grains lining cavities, the central parts of such cavities being usually filled in with quartz, or calcite, or both.

Another and more widely-spread form of occurrence is as anatase in small double pyramids, with or without the prism-band, exactly as in the altered Coniston Flags at Shap.[2] These anatase crystals were first noticed in a slate from Honister Crag, and some difficulty was at first experienced in accepting the true nature of their origin. I was disposed to regard them as having been introduced in metamorphosed sedimentary fragments, as in the case of the tuff at Falcon Crag, and to suppose that the crystals had remained distinct after the other material of the fragments had been completely obliterated and absorbed into the rest of the slate. But longer observation of this particular occurrence, and of numerous others subsequently found, quite dispelled that idea. There is no doubt that the solutions which have permeated the ash-beds, and which have acted under high pressure (as witnessed by the bubbles in the calcite) and probably high temperature also, have dissolved titanic acid and allowed it to re-crystallize (according to differences of conditions we are not able to specify), either as anatase, more sparingly as rutile deposited in cavities, or in combination with silica and lime as sphene. The anatase occurs mainly as clusters in patches of chlorite. With the perfect crystals are often large numbers of grains not showing definite forms, but apparently deposited at the same time. The mineral occurs also in secondary quartz-grains which are abundant in some of these rocks; in calcite, though rarely, and now and then in felspar-substance. In some cases cavities are seen lined with rutile, and filled in with quartz in which are perfect little crystals of anatase; so that between the time of deposit of the rutile on the sides of the cavity and the final in-filling with quartz a change of conditions as to nature or temperature of solutions, or both, had taken place, which altered the crystal-forms of the titanic acid being deposited.

It may be noted that in slates which show very much sphene anatase does not usually occur. Otherwise a large number of the

[1] It is also to be remarked that the small crystals of tourmaline, so usual in clays, shales, and slates, are never seen in these ashes.

[2] Since the above was in print, I have had the opportunity of examining some of these minute anatase crystals by means of a $\frac{1}{12}$ inch oil-immersion objective. This has enabled me to see them very much better than I ever did before, and to ascertain that I was mistaken in stating that the prism-band is present on some of them. The apparent band disappears when the crystals are seen under the great magnification, together with fine definition, which the use of this objective gives us.

slates contain it in varying amount, sometimes very scarce and sometimes in crystals so small as to require very careful search for its detection, but at other times very abundantly and of larger sizes, ranging up to $\frac{1}{300}$th of an inch in length.

The various experiments on record as to the artificial formation of crystallized titanic acid by sublimation show that variations of temperature cause variations in the resultant crystal-form;—rutile, anatase or brookite being obtained at different parts of the apparatus. Similarly the three minerals may be obtained by fusion of titanic acid in different solvents. The same no doubt applies as regards solutions of titanic acid in liquids, and its crystallization out of them under various conditions; but there appear to be very few experimental data as to this, and we can only speculate as to the exact nature of the solutions which have acted in these rocks. It is stated by Doelter (Allgemeine Chemische Mineralogie, p. 155) that by means of water containing sodium fluoride he succeeded in re-crystallizing titanic acid in the form of rutile. He also gives interesting figures (*loc. cit.* p. 189) showing a very noticeable solubility of titanic acid (powdered rutile) even in pure water, in sealed tubes at 80° C. From various considerations it is probable that the solutions acting in these rocks were largely charged with alkaline silicate; a solution of alkaline titanate was probably formed at the same time, out of which carbonic acid would liberate titanic acid. It seems likely that so far as concerns temperature, pressure, etc., the conditions existing in many of these beds of the Borrowdale Series when the main changes took place, did not materially differ from those under which the Coniston Flags at Shap were metamorphosed near the granite, exactly similar solution of the titanic acid and re-crystallization as anatase having taken place in some of these flags (Harker and Marr, Quart. Journ. Geol. Soc. vol. xlvii. 1891; also Hutchings, Geol. Mag. 1891, p. 462).

Among the various changes which have taken place in the minerals of these rocks, those which concern the felspars have the greatest interest. The points involved are, of course, the same whether we study the felspars in the slates and other detrital rocks or in the altered andesites, and what follows may be taken as applying equally to both classes.

The normal decomposition of the felspars of these rocks does not seem, so far as can be made out, to lead to kaolinization.[1] The three main types of decay, sometimes singly, sometimes together, give rise respectively to white mica, a very pale chloritic mineral, and calcite. The formation of white mica is very usual all over the district. In many andesites and ashes the felspars, while retaining their original outlines perfectly sharply, are internally quite full of mica flakes, often of good size, hardly ever showing any sort of orientation to the crystal-planes of the containing crystal, but occurring equally in all directions and often as tangled clusters of flakes at all azimuths. This lack of orientation of the mica formed in felspars appears to be not unusual. I have noticed it in other rocks; and it is pointed out by Rosenbusch (Microscop. Physiog. der Gesteine, p. 23).

[1] It is usually considered to be difficult, and indeed often impossible, to distinguish

Among the mica in the larger crystals may often be seen quartz, and usually more or less of perfectly glassy clear felspar.

Where the alteration has given rise to the pale chloritic mineral, a more definite orientation appears to largely prevail. This chlorite is very faintly dichroic, and polarizes in thin sections in tints up to yellowish-white of the first order.

Calcite frequently accompanies the other two products, and often occurs by itself, in all stages up to the total replacement of felspar crystals by pseudomorphs in calcite.

Mr. Alfred Harker, in a petrological appendix to a paper by Prof. Nicholson and Mr. Marr ("The Cross Fell Inlier," Quart. Journ. Geol. Soc. vol. xlvii. pp. 512–525), alludes to the fact that in some of the rocks in question the evidence goes to show that a large part of the felspars are "regenerated," and have a secondary twinning due to crushing. He specially alludes to a rock from Wythwaite Top, giving details as to his observations on the porphyritic felspars contained in it and their alterations (p. 515).

Similar occurrences may be noticed more or less all over the Lake District, and these rocks offer a splendid field for the investigation of the many questions, as yet only partially understood, as to the re-generation and re-crystallization of felspars, with or without secondary twinning, due to crushing and shearing. Specimens may be obtained at many points from ashes (fine tuffs and slates), and often from altered lavas, in which the usual turbid felspars full of mica, chlorite, or calcite, with the twinning nearly or wholly obliterated, are replaced by more or less glassy clear crystals often beautifully twinned. These are not crystals and fragments which have escaped decay, but are obviously felspars which are re-formed *in situ*,—often, apparently, completely re-crystallized and re-twinned. The rocks in which these occur all give full evidence of great stresses, and the felspars themselves are often bent, broken, and re-cemented with chlorite in a most complex manner.

In the slates of Honister Crag, and many other quarries, any number of bits may be seen, as clear as fragments of window-glass except for a little brownish dust in some cases, a large proportion of such bits showing beautiful twinning in polarized light. Many other bits, equally clear and glassy, show no twinning whatever, nor any cleavage, and are only to be discriminated from quartz by

microscopically between kaoline and muscovite as alteration-products in decomposing felspars. Rosenbusch, for instance, points this out very emphatically (Physiographie der Mineralien, pp. 516, 561). The flaky alteration-product in felspars is certainly sometimes so minute, and occurs in such an indistinct manner, that decision as to its exact character is very uncertain or impracticable. But as soon as the flakes are larger and more distinct (and this is often eminently the case in the rocks now under consideration), I venture to think that the identification of the mica can be safely made. The bi-refraction of kaolinite is high, but so far as my observations go it is *very distinctly* less than that of muscovite, observing transverse sections in each case. Then again, edge-sections of the mica extinguish parallel, while edge-sections of kaolinite give such very decided angles that no confusion of the two minerals appears possible. I have used for these comparisons the well-known kaolinite crystals from Anglesey, and also those which occur abundantly (though of smaller size) in the interstices of many coarse sandstones and grits of the Coal-measures.

optic tests in convergent light; and in some cases, in tuffs, large decayed felspar-fragments have been re-generated into mosaics of clear grains in the well-known manner.

What these felspars now are it does not seem possible to decide on optic tests alone, in thin sections. The multiple twinning in most cases points to plagioclase, and extinctions appear to indicate albite, oligoclase, and andesine as probably the varieties. But nothing short of a laborious isolation and analysis of specimens could give a safe decision. It appears to be usually considered that albite and andesine are the varieties chiefly produced by the dynamic re-generation of decayed original felspars.

In the paper above referred to Mr. Harker brings forward the question of the formation of new felspar by deposit in vesicles, and describes a case of such an occurrence in one of the Cross Fell rocks, the felspar in question being well-twinned plagioclase with extinction-angles pointing to albite or andesine.

According to my own observations, this mode of occurrence is not by any means very rare, and I can point to several cases of cavities in these rocks which are lined with chlorite, etc., and contain felspar in such a manner as to apparently forbid any other explanation than that the mineral has been crystallized from infiltrations into the cavities. The question first attracted my attention in connexion with the altered rocks round the Shap granite. Messrs. Harker and Marr allude to felspars formed in vesicles by the metamorphism of their contents. They refer to one particular slide in which this is observed, but state that it does not seem to have commonly occurred. Whether it be due to contact-action or not, my own impression is that it is very usual at some points round the granite, as I have several slides in which well-defined felspar, often in good large individuals, frequently occurs in vesicles with quartz, biotite, hornblende, etc. It is mostly plagioclase, but I have one slide, which I have submitted to Mr. Harker, in which occur grains of what seems to be orthoclase, perfectly clear, beautifully cleaved, and extinguishing quite parallel to the cleavages. One such grain is over $\frac{1}{4}$ inch in diameter filling an irregular cavity, which may have been a vesicle, but seems more likely to have been due to the removal of some former mineral. I at first attributed these large grains, as also the smaller plagioclase in vesicles, to the action of the granite, and this may be correct, but it is not necessarily so, as later observations showed me that all these occurrences are paralleled in rocks far outside the contact-zone. Cavities with plagioclase, and apparently also orthoclase, occur not rarely in the coarser slates at Mosedale, for instance; and the grains of well-cleaved felspar, apparently orthoclase, are seen again in sections of the andesite of Harter Fell, Mardale, where the mineral occurs in a precisely similar manner as large, irregular, perfectly glassy-clear, untwinned grains in a rock whose original felspars are all sharply and definitely bounded, and are now exceedingly turbid.

I look upon all these cases as due to causes wholly distinct from the dynamic regeneration of decayed felspars, and as explained by

simple deposit from solutions, exactly as albite, orthoclase, etc., are known to be deposited on a larger scale in veins and cavities.

There are also, so far as I can make out, what certainly appear to be orthoclase crystals in some of these rocks, which seem to require another explanation. They are not in cavities, and for various reasons they do not appear to be original crystals, but to be "regenerated" like so many of the plagioclase crystals. I have come, after much consideration of them, to regard them as not improbably pseudomorphs after former plagioclase, on the theory (or hypothesis) that solutions containing silicate of potash have acted upon these former felspars, removing soda and lime and replacing them with potash, One such crystal observed, which optically fully corresponds to orthoclase, contains a cavity lined with deposited rutile, evidently formed at the time that solutions were strongly acting on the original crystal.

In some of the normal andesites the much-altered felspars full of mica, chlorite or calcite, show in among these secondary products, as before stated, more or less of clear glassy material. It is not an uncommon thing to see this glassy felspar in considerable quantity in long streaks and patches, and where the outline of the crystal is fully preserved, as often is the case, to see that this felspar is optically uniform all over the crystal, is quite free from twinning and extinguishes perfectly parallel to the crystal-boundaries, or at angles which point to orthoclase. In some of the rocks crystals are frequent which are wholly glassy clear, save for trifling inclusions, and behave as above described, occurring together with plagioclase which is obviously regenerated.

Such changes as I suggest may have taken place do not appear at all unlikely under the conditions which we have reason to infer obtained during the alterations these rocks have undergone, and there appears to be good independent evidence that they have been observed and chemically proved elsewhere. A leading authority in this class of investigation appears to be Lemberg. I have not at present an opportunity of consulting his original papers, but in Roth (Chemische Geologie, vol. i.) among other abstracts from and references to Lemberg's work are certain facts which bear very directly on the point in questions.

Thus, Lemberg analyzed oligoclase from the tourmaline-granite of Monte Mulatta, and its green alteration-products in four examples, *a*, *b*, *c*, *d*. The alkalies were as follows:—

	Original Oligoclase.	*a.*	*b.*	*c.*	*d.*
Soda =	7·26 per cent.	2·14 p.c.	0·70 p.c.	2·23 p.c.	0·84 p.c.
Potash =	2·10 ,,	3·00 ,,	5·28 ,,	4·54 ,,	7·43 ,,

water is also taken up at the same time.

Other analyses of Lemberg's are also given, showing similar changes in oligoclase, some chloritic mineral being apparently formed, with a simultaneous removal of soda and increase of potash. An analysis of labradorite is also given, together with that of its alteration-product, showing—

	Original labradorite.	*Alteration-product.*
Soda ...	5·43 per cent.	0·88 per cent.
Potash...	0·92 ,,	8·51 ,,

and in another still more extreme case the alteration-product contained Soda = 0·17 p.c.; Potash = 9·71 p.c.

From this latter alteration-product acid extracted 37·61 p.c. of a silicate of magnesia, alumina and iron oxides,—evidently a chloritic substance. The residue left after this extraction contained very nearly all the potash, "and corresponded in composition to orthoclase." These alterations appear to be exactly cases of what I suppose to have taken place in some of the andesites.

A chloritic mineral is formed, with a simultaneous more or less extensive *chemical* alteration of the soda-lime felspar, tending to convert it into orthoclase. In these Lake District rocks powerful dynamic action, following on the chemical change, may be supposed to have completed the work in *re-crystallizing* the felspar-substance. It will not affect the question, whether chlorite, mica or calcite is formed during the chemical stages of these processes.

In commenting on the above results of Lemberg, Roth points out that it is not indicated from what source the potash was supplied which was taken up during the changes of the felspars. In the case of the rocks we are considering there is no difficulty as to such source. I have shown how frequently white mica is formed in the alteration of some of the felspars of these rocks, and how specially and very largely this is the case in the beds of fine ash and tuff. In these ash-beds the finely-pulverized material has undergone these alterations as a *whole*, including the portion which in the massive andesites is consolidated as ground-mass, considerably richer in potash than the rest of the rock, but undergoing these changes, as a rule, in a very much less degree.

These changes, as we have seen, entail a considerable liberation of potash as soluble silicate, and we may be sure that during their progress all these rocks, as a whole, were permeated by solutions containing that salt, and also carbonate of potash. These solutions would play an important part in further changes, and acting upon soda-lime felspars (themselves containing more or less of potash) already in course of decay, would easily and naturally bring about the alterations supposed. No doubt similar explanations would apply in the cases proved by Lemberg.

Lemberg was apparently able to isolate the special felspars, the alterations of which he wished to study. Such isolation is, unfortunately, not possible in the case of the rocks to which I refer. The felspars are so small that the picking-out of them is not practicable, and their isolation from the crushed rock by means of dense solutions is a tedious and difficult matter. Also it is not possible in this manner to separate the different *varieties* of felspar one from the other, as even in the most favourable of the occurrences examined, the included secondary minerals, though small in amount, suffice to completely counteract the normal differences of specific gravity.

Under these circumstances it has not been possible to obtain any very effective chemical evidence on the point in question.

The most favourable rock in my possession is an andesite from a point not far from Ulleswater, on the road to Matterdale. Its ground-mass is fine-grained, and appears to have been originally "hyalo-pilitic." There are numerous well-defined pseudomorphs of chlorite after augite. The porphyritic felspars are numerous, but small, ranging from about $\frac{1}{25}$th of an inch in length as maximum. They are largely more or less glassy clear, and contain comparatively little of secondary minerals;—chlorite, calcite, a little epidote, with but little mica in this case.

A good many of them show the appearances above stated which lead me to suppose they are perhaps orthoclase. The rest are plagioclase, of which, as usual, it is not possible to safely determine the variety, though oligoclase appears to be present. A large piece of this rock was pulverized and reduced to uniform very small grains by means of wire gauzes of suitable mesh. The powder was subjected to repeated separations in liquids of diminishing specific gravities, the lighter portions being successively concentrated, a final separation being made in a liquid in which a fragment of pure labradorite just remained suspended. In this manner, with plenty of time and patience, it was possible, in spite of the unfavourable nature of the rock and of the smallness of the grains, to separate from a large bulk a small quantity of material which proved to be felspar, free from ground-mass, and contaminated only by small amounts of chlorite and calcite. This was finely powdered, digested a short time in hydrochloric acid of moderate strength (sufficient to decompose chlorite), and finally in dilute potash liquor to remove separated silica. The residue, well washed and dried, was practically pure felspar.

A sample of the bulk of the powdered rock contained: Silica, 62·43 per cent.; Soda, 4·13 per cent.; Potash, 2·28 per cent., as kindly determined for me by Dr. J. B. Cohen. This does not differ appreciably from the average run of analyses of local andesites, though the potash is perhaps a trifle higher than usual.

The isolated felspar-substance was analyzed by Mr. Paterson and contains Soda 8·52 p.c.; Potash 4·1 p.c.

Having regard to the facts that in all rocks of this class the potash concentrates in the ground-mass, and that the average of the entire rock is here only 2·28 p.c., we should not expect to find anything like so much as 4 p.c. potash in the porphyritic felspars. Its presence in them in this amount would seem to justify the inference that some of them are specially rich in it, and that, indeed, some potash-felspar is probably present together with the plagioclase.

In some of these rocks, again, there appear to be examples of those very interesting phenomena which have been so beautifully described and illustrated by Prof. Judd in his paper, "On the Growth of Crystals in Igneous Rocks after their Consolidation" (Q.J.G.S. vol. xlv. 1889).

They are not so large nor so striking as the instances quoted and

figured in that paper, but there are in some specimens crystals which show all the principal appearances enumerated by Professor Judd, and which cannot, I think, be explained satisfactorily in any other manner than that which he has given us.

NOTICES OF MEMOIRS.

I.—The Oolitic Rocks at Stowe-nine-Churches, Northamptonshire. By Beeby Thompson, F.G.S., etc. (Journ. Northamptonshire Nat. Hist. Soc. Vol. VI.)

IN this paper Mr. Thompson describes a section of especial interest, as it shows the sequence of beds from the Northampton Sands to the Oxford Clay. The tract near Stowe, situated about seven miles west of Northampton, is a faulted one, and to this cause is due the preservation of the Great Oolite and higher beds, which elsewhere in the immediate neighbourhood have been removed by denudation. The beds have been quarried chiefly to supply limestone for fluxing purposes to the Heyford furnaces near by.

The chief new points in this paper concern the identification of the small area of beds overlying the Great Oolite, as these were not indicated on the Geological Survey Map. The highest bed beneath the Drift soil is a blue clay grouped as Oxford Clay. There can be little doubt that this represents the clay usually found between the Cornbrash and Kellaways rock, and sometimes designated the Kellaways Clay.

The Cornbrash contains some of the usual fossils met with in the formation, and it rests on a series of beds grouped with the Forest Marble and Great Oolite Clay. The presence of beds of flaggy limestone resembling varieties of Forest Marble is of interest, as they are only occasionally met with in the country to the north-east of Bicester, in Oxfordshire.

The Great Oolite Clay is not, as Mr. Thompson thinks, the bed to which the term 'Cornbrash Clay' has been applied; that Clay, where it occurs, overlies Cornbrash rock, partly replaces it, and passes up into the Kellaways Clay.

The Great Oolite Limestone and lower beds are described by Mr. Thompson, and lists of fossils are given from these as well as from the higher strata. A photographic plate and a plate of diagram-sections illustrate the paper. H. B. W.

II.—Notes on the Fossil Aphidæ and Tettigidæ.

IN Mr. G. B. Buckton's late Monographs on British *Aphides* and *Cicadæ*, are thoughtful remarks on the known fossil forms of these two great families of Insects, and we here reproduce them as interesting to our readers,—premising that these Insects belong to the *Homoptera*, whose zoological relationship is as follows—

Hemiptera: A. Homoptera: *Aphides, Coccidæ, Cicadæ, Fulgoridæ*, etc.

B. Heteroptera: *Hydrocorinæ* (Water-bugs), *Geocorisa* (Land-bugs).

II. In the "Monograph of the British *Aphides*," vol. iv. 1883, Ray Society, at pages 144—178, Mr. Buckton gives a sketch of the geological occurrences of Insects in general, and of the *Aphidinæ* in particular, and finds that the *Hemiptera* are nearly as ancient as the *Coleoptera*, and apparently preceded the *Diptera*, *Hymenoptera*, and *Lepidoptera*. The earliest known *Aphides* have been recognized by Westwood, as collected by Brodie in the Purbeck beds of Wilts and Dorset. In the Eocene Tertiaries of Europe Aphis occurs fossil; and even if not present, its enemies who fed on it (*Syrphidæ* and *Coccinellidæ*) and others (Ants) that sought its honey-dew, have left their remains. At Radaboj in Croatia, and Œningen in the valley of the Rhine, *Aphides* are present in Miocene strata. Indeed in the Swiss Miocene 136 species are known. The *Aphididæ* of North America have been described by Scudder from the White-River District in Utah, and the Green-River-Station in Wyoming; also from the Florissant-Lake strata in Colorado, the last giving eight species of *Aphidinæ*. The many species of *Aphides* found in Amber have occupied the author's attention (pages 160–168). He gives a lucid account of what has been published about Amber and its origin; and indeed he also alludes to what geologists have determined about the Tertiary and other strata in which *Aphides* occur, and especially about the flora represented by the plant-remains accompanying these Insects at the several localities.

Plate cxxxi. contains figures (after Berendt) of Germar and Berendt's species from Amber; namely, three of *Aphis* (?) and two of *Lachnus* (?), carefully described in the text.

In plate cxxxii. Mr. Buckton figures, from earlier drawings, one *Aphis* (?) from the Purbeck; one from the Tertiary of Amberieux (Ain); one *Aphioides* from Amber; four of *Aphis* (?) and three of *Lachnus* (?) from Radaboj; and a *Pemphigus* (?) from Œningen.

Some fossil *Aphides* from Florissant, Colorado, are figured (after Scudder) in plate cxxxiii. Five new genera are described by Buckton, at pages 176–178, as *Siphonophoroides* (2 spp.), *Archilachnus*, *Anconatus*, *Schizoneuroides*, and *Pterostigma* (1 sp. each).

III. In Mr. G. B. Buckton's "Monograph of the British *Cicadæ* or *Tettigidæ*," 1891, Macmillan & Co., London and New York, some fossil forms are referred to in vol. ii. at pages 164–184.

After some remarks on the bibliography of Fossil Insects, their occurrence in freshwater rather than in marine deposits, their local abundance in isolated groups or masses, and the possible conditions of preservation, the author observes that the *Hemiptera* lived in Carboniferous times in the American and British areas, contemporaneously with the gigantic *Dycteoptera* (Cockroaches) and *Coleoptera* (*Buprestidæ*) which crawled amongst the Equisetums and Tree-ferns of that early period. A few Hemipterous remains are described by Scudder from beds below the Lias or Rhætic in Colorado; and some specimens from the Rhætic at Schönen in Sweden have been referred to *Cimex* and *Cicada*. From the Rhætic (?)

of Schambelen (Aargau), Switzerland, O. Heer enumerates 143 fossil Insects, of which 12 are *Hemiptera*. The Jurassic *Palæontina oolitica*, from Stonesfield, was referred by Mr. A. G. Butler to *Lepidoptera*, but others believe it to belong to *Cicadæ*. In some of the Purbeck beds of Wilts and Dorset Insects are known to be abundant, as shown especially by Brodie and Westwood, in 1844 and 1854. Of the *Tettigidæ*, Prof. Westwood determined remains of a small *Cicadellina*, and of a *Cercopis* and *Bythoscopus*. Though Insect remains are plentiful in many Eocene Tertiary beds, only in the gypsum of Aix-en-Provence have discoveries of *Cercopidæ*, *Cixiidæ*, and *Cicadellinæ* been made.

To the Oligocene period Mr. Scudder refers the remarkable fresh-water insectiferous deposits of Colorado, which form part of islets in the Florissant Lake. The fauna and flora agree partly with those of Œningen near Schaffhausen, and Radaboj in Croatia, which belong to the Miocene. In British Columbia, Dr. G. M. Dawson discovered some lacustrine insect-bearing strata, believed also to be Oligocene in age; and they have yielded to Mr. Scudder 19 *Hemiptera*, of which only two are truly Hemipterous; whilst there are eleven Homopterous *Cercopidæ*, three *Fulgoridæ*, and two *Aphidæ*. All are of larger size than the usual Tertiary Insects. Of all the American fossil insects, from areas far apart, 612 species have been described, of which the *Hemiptera* form the large proportion of 266 species, and Mr. Scudder regards the known European species of *Hemiptera* as numbering 218.

The Miocene of Switzerland has yielded multitudes of fossil Insects, mostly discovered and described by O. Heer. Among them are 636 Hemipterous species; and by far the majority of these are larval forms. The presence of at least one *Cicada*, and the numerical preponderance of *Reduviidæ*, *Scutata*, and *Coreodeæ*, also the occurrence of several fine *Cercopidæ* and large Water-bugs, give good evidence that a warmer climate (especially milder winters) then prevailed over Central Europe than now. O. Heer thought also that as these insects undergo an incomplete metamorphosis, and are more or less active in their pupal conditions, they were better suited to regions not subjected to the rigours of long cold winters.

From the Miocene of Greenland and Spitzbergen examples of *Cercopis* and *Pentatoma* have been obtained. From New South Wales Mr. R. Etheridge, jun., has described (1890) the fossil *Cicada Lowei*.

The Amber of the Baltic and elsewhere (pp. 171–173; see also "Monogr. Aphides," pp. 160–165) contains many specimens of *Tettigidæ*, of these Mr. Buckton's Plate G illustrates two specimens of *Typhlocyba*, two (?) of *Jassus*, one of *Tettigonia*, and four of *Cixius*; also one *Cicada* in copal-resin from Zanzibar.

Of other fossil *Tettigidæ*, Mr. Buckton's Plate F illustrates Butler's *Palæontina oolitica* (elytron); two species of *Cicadellium* and one of *Cercopidium*, from the Purbecks; one *Cicada* and two species of *Cercopodium* from the Swiss Miocene; one *Agallia*, one *Petrolystra*, and one *Palæcphora*, from the Oligocene of Colorado; also

a *Thammotettix*, a *Dawsonites*, and a *Stenecphora* from the Tertiary of British Columbia.

At pages 178–181 Mr. Buckton refers to geological speculations as to the changes of land and climate affecting Insect-life in late Tertiary and Quaternary times; also to possibilities of development and of degeneration among Insect forms in geologic times, and he hesitates to offer any outline of the phylogenetic descent of the *Homoptera* in particular. T. R. J.

REVIEWS.

I.—The Cause of an Ice Age. By Sir Robert Ball, LL.D., F.R.S., Royal Astronomer of Ireland. Pp. 180. (Kegan Paul, Trench, Trübner & Co. 1891.)

THIS little book contains a very clear and agreeably written exposition of the commonly received Astronomical theory of Glacial periods. But it goes further than that, because it offers an explanation of a difference of the mean temperatures of either hemisphere during the summer and winter seasons, reckoning from equinox to equinox, which has not hitherto been taken due account of in estimating the effects of the earth's position with reference to the sun. The author proves, by a short calculation given in an Appendix, that owing to the obliquity of the ecliptic the quantity of heat, received from the sun upon one hemisphere during its summer, bears to the quantity received during its winter the invariable proportion of 63 to 37. This will be the case always, whatever be the position of the equinoctial line with respect to the major axis of the orbit, and whatever be the eccentricity of the orbit. He points out that, in consequence of an inadvertence in a statement in Herschel's Outlines of Astronomy, the proportion has hitherto been regarded as one of equality; and it is obvious how great a difference this consideration will make in estimating climatic effects.

The greatest eccentricity which the earth's orbit can have is about 0·07. When with this eccentricity winter in the northern hemisphere occurs in aphelion, taking the mean daily heat for the whole year received by that hemisphere, as unity, the mean daily heat received by it in a short summer of 166 days will be represented by 1·38; and the mean daily heat received in its long winter of 199 days will be only 0·68. This, the author says, will produce a severe glacial epoch, when the summers will be short and very hot, and the winters long and very cold. While the eccentricity remains the same (for it changes very slowly) when the axis of the earth is next carried round by precession until the winter occurs in perihelion, the mean daily heat received in a long summer of 199 days will be 1·16, and in a short winter of 166 days will be 0·81. This he believes will produce an interglacial period—interglacial because two or three such reverses may occur before the eccentricity is sensibly altered. It must be remembered that the unit of heat here used is a very large one, being that which raises the mean temperature of

the hemisphere from that of space to that which it actually has, which rise may be perhaps measured by 300° F.; so that 0·1 may represent a difference of 30° F. The above may suffice to point out the importance of the work in regard to the astronomical theory of the Glacial epoch. It adds fresh force to Dr. Croll's hypothesis.

There appears to be a slip at p. 95, where it is said that, "with the present eccentricity of the Earth's orbit, the greatest possible difference between summer and winter would amount to 33 days, etc." Such a difference could only occur when the eccentricity had its highest value of 0·07, whereas at present its value is only about 0·017.

Sir Robert Ball does not venture to say when the last ice age took place, nor when the next may be expected; but only that, when they do occur, they will be separated by 21,000 years with interglacial periods intervening. Prof. Darwin, in his notice of this book in "Nature," Jan. 28, regrets this reticence, and inquires whether Leverrier's formulæ, which Croll used, may not be relied on to give an approximation to the value of the eccentricity for about 100,000 years in the past. Croll constructed an elaborate chart, showing the eccentricity for three millions of years in the past, and one million in the future. Considering the enormous labour with slight mathematical powers at his disposal, it makes one sad to think that much of this labour was not more profitable; but if the formulæ can be depended on for 200,000 years in the past, an eccentricity of 0·0569 occurred at about that date, which, on his hypothesis, might have been sufficient to bring about the Glacial epoch.[1]

Looked at from the geologist's point of view, this book seems rather too triumphant. The author appears to think there are fewer difficulties remaining than the geologist would admit. For instance, he attributes the climate of what are now Arctic regions, at the time when a luxuriant flora flourished there, to an interglacial period. But, seeing that a single night of severe frost will kill a fig-tree, it is hardly credible that, even with a short winter and a nearer sun, frosts should never have occurred at a place within the Arctic circle, which would have been fatal to such vegetation.[2] Again, he points out that the astronomical theory necessitates the recurrence of glacial epochs through all past geological time, and to explain away the objection that glacial deposits and scratched stones are not to be met with to testify to their frequent recurrence, he refers to the unconsolidated and perishable nature of such deposits. But Till and Boulder-clay are less destructible than many clays, and other unconsolidated deposits, which have been buried again and again under newer strata without being disturbed; and they occur in India possibly in Palæozoic strata.[3]

Other points will occur to the geologist where difficulties appear to be passed over. But although a few passages betray that "The

[1] See a paper on the Ages of the Trail and Warp by the writer, GEOL. MAG. Vol. IV. pp. 193–199, 1867.

[2] See discussion on Prof. O. Heer's paper on fossil plants from North Grinnell Land; Quart. Journ. Geol. Soc. 1878, vol. 34, p. 70.

[3] Quart. Journ. Geol. Soc. 1878, vol. 34, p. 375.

Cause of an Ice Age" is not the production of a professed brother of the hammer, nevertheless it will well repay perusal, and all must acknowledge that a valuable contribution has been made by a distinguished ally, bearing upon one of the most difficult problems of our science. O. Fisher.

II.—Palæozoic Fishes.

1. On the Characters of some Palæozoic Fishes. By E. D. Cope. Proc. United States National Museum, Vol. XIV. (1891), pp. 447–463, Pls. XXVIII.–XXXIII.
2. Ueber *Pterichthys*. By J. Victor Rohon. Verhandl. Russ. Kais. Mineral. Ges. St. Petersburg, Vol. XXVIII. (1891), pp. [1–25 reprint], Pl. VII.

OUR knowledge of the Palæozoic Fishes is still progressing rapidly both in Europe and America, and we have lately received the two papers on this subject quoted above. Prof. Cope's communication is divided into seven parts, and deals with several important types; Dr. Rohon's work is chiefly an examination of the histological structure of the shield of *Pterichthys*.

The first fossils noticed by Prof. Cope are referable to Elasmobranchii. A detatched tooth from the supposed Permian of eastern Nebraska, named *Styptobasis Knightiana*, is very remarkable on account of the small size of its base of insertion; we should, indeed, prefer to have some information as to its microscopical structure before accepting the fossil definitely as an Elasmobranch tooth. A typical spine of *Ctenacanthus* (*C. amblyxiphias*, sp. nov.) from the Permian of Texas is a noteworthy discovery; and the first truly hybodont fin-spine met with in the New World (*Hybodus regularis*, sp. nov.) is also of much interest, though it is not Palæozoic, being from the supposed Trias of Baylor County, Texas.

The Elasmobranch fragments are only of limited importance, but Prof. Cope's description of the cranium of *Macropetalichthys*—one of the most remarkable and least understood American Arthrodira or "Placoderms"—tends towards a considerable advance in our knowledge of the great extinct group of fishes to which it belongs. As pointed out by Prof. Cope, this genus is not related in any way to the Sturgeons, notwithstanding the contrary assertions of several observers; and the plates of the head-shield are shown to be arranged much as in *Coccosteus*, *Dinichthys*, and the other Arthrodira. The hinder part of this shield, it is stated, "does not seem to have protected the brain, but rather the anterior part of the vertebral axis, and seems to have been a nuchal plate." Exactly the same opinion has already been expressed in reference to the so-called "occipital region" of the Scottish *Homosteus* (Proc. Zool. Soc. 1891, pp. 198–201). The base of the cranium in an Arthrodiran is now described for the first time, Professor Cope's specimens of *Macropetalichthys* displaying a good deal of this region; and the detailed anatomical description is followed by a discussion of the relationships of this type of fish in the light of the new facts adduced. On the

whole, Prof. Cope is inclined to accept the conclusion arrived at in the British Museum Catalogue of Fossil Fishes; namely, that the Arthrodira are extremely specialized Dipnoi. "The nuchal portion [of the head-shield of *Macropetalichthys*] with its lateral nuchal elements is represented by the cartilaginous mass which extends posterior to the median occipital bone in *Ceratodus*, in which this region has very much the form of the nuchal shield in *Macropetalichthys*, although it is relatively shorter. The chordal groove with its descending laminæ resembles much the produced occipital bone of *Lepidosiren*. The parasphenoid in both *Lepidosiren* and *Ceratodus* is produced posteriorly abnormally, and it is only necessary to imagine this part to be reduced to its normal length to have the conditions found in *Macropetalichthys*. The broad parasphenoid and vomer remind one of that of *Ctenodus*. As I have shown that *Macropetalichthys* is allied to *Dinichthys*, we can add in favour of the supposition of affinity to the Dipnoi the peculiar dentition of that genus. The ectetramerous structure of the dorsal fin shown by Von Koenen and Traquair to exist in *Coccosteus*, and shown to be probably present in *Dinichthys* by Newberry, are in favour of the Dipnoan theory."

Prof. Cope evidently continues in the belief that *Pterichthys* and its allies have no connexion whatever with the Arthrodira; and the researches of Dr. Rohon quoted above come as a welcome confirmation of this view. Dr. Rohon points out that the histological structure of the shield of *Pterichthys* is very different from that of *Coccosteus*, and closely similar to that of *Pteraspis*, *Trematapis*, and their allies. This result also confirms the arrangement of the early fishes in question in the second part of the British Museum Catalogue.

Prof. Cope's remarks on the limbs of *Holonema* and *Megalichthys*, however, are far from satisfactory. In the first place, we venture to re-affirm that the so-called dorsal shield of *Holonema* is really the ventral shield turned the wrong way forwards; and the genus belongs to the Arthrodira, not to the Ostracodermi. The limb referred by Prof. Cope to *Holonema* is the distal segment of the arm of *Bothriolepis*, originally named *Stenacanthus* by Leidy. It is stated that "the spine differs from that of both *Bothriolepis* and *Pterichthys* in being without complete segmentation;" on the other hand, we may remark, the distal half of the arm of *Bothriolepis* is nearly always incompletely segmented. With regard to the paired fins of *Megalichthys*, which are said to "approach those of the Arthrodira very distinctly," we venture to assert, from a knowledge of other Osteolepidæ, that the apparent simplicity of the arrangement of the cartilages in Prof. Cope's specimens is due to imperfect preservation, while the paired limbs of the Arthrodira are far too imperfectly known to admit of comparison.

The final result of Prof. Cope's researches in the Crossopterygian ganoids is of great interest, and briefly summarized in an amended classification, which we propose to consider elsewhere on a future occasion. The Professor is at last converted to the belief that the Palæoniscidæ and Platysomidæ are closely related to the primitive

Sturgeons; and he concludes his memoir by the description of two new species of *Platysomus*, one from the Permian of the Southern Indian Territory, the other from the Coal-Measures of Mazon Creek, Illinois. A. S. W.

III.—The Story of the Hills: A Popular Account of Mountains and How they were Made. By Rev. H. N. Hutchinson, B.A., F.G.S. (London, Seeley & Co., 1892.)

POPULAR works on geology are rapidly multiplying, and it becomes more and more difficult to devise any new method of treatment of the subject. Mr. Hutchinson's little book, however, is a pleasing novel version of the old story, interwoven with much interesting information outside the geologist's sphere and illustrated by very beautiful photographs of scenery. There are also numerous extracts from Ruskin's "Modern Painters," from Geikie's "Scenery of Scotland," and from other well-known prose-writers and poets that help to enliven the volume. Mr. Hutchinson's style is terse and clear, without technicalities, and thus precisely adapted to the general reader for whom the "Story" is intended.

The first section of the book deals with mountains as they are. The functions of mountains as barriers between races of men, as retreats for conquered tribes, and as influencing climate, are treated in succession. Mountain plants and animals are then discussed, with special reference to the Alps of Central Europe.

The second and larger section of the book is concerned with the manner in which mountains were made, and is purely geological. Mr. Hutchinson compares the making of a mountain with the building of a cathedral, describing in succession the three processes of "transportation, elevation, and ornamentation" of the materials. Volcanic mountains also have a special chapter; and the volume concludes with some general considerations on the age of mountains.

On all points the information is varied and well up to date, and Mr. Hutchinson's little book may be recommended alike to the school-boy naturalist and to the ordinary mountain-climber who desires to know something of the nature of the peaks and passes among which he spends his holiday.

IV.—Catalogue of the Type Fossils in the Woodwardian Museum, Cambridge. By Henry Woods, B.A., F.G.S. (Cambridge, University Press, 1891.)

THE Woodwardian Museum contains so large a series of fossils to which reference has been made in published works, that a Catalogue like the present will prove of much value to all who are actively engaged in palæontological research. More especially is this the case, since the Woodwardian Professor has full power to exercise his discretion in lending the specimens under his charge to competent investigators far from the University of Cambridge. It is now possible to determine at a glance whether or not any particular type or described specimen occurs in the Woodwardian

collection, and much labour and time will thus be saved in making enquiries.

The Catalogue is prefaced by some general remarks by Professor Hughes, who directs attention to the historical interest of some of the older collections in the Museum. The original cabinet of Dr. John Woodward includes that of the Sicilian naturalist, Agostino Scilla, born in 1639; and another collection of the seventeenth century is that of Lister, who opposed the views of Scilla in an article entitled "De Conchitis sive Lapidibus qui quandam similitudinem cum conchis marinis habeant." These are not catalogued in the volume before us, which deals only with the collections of the present century.

Of the principal modern collections an alphabetical list is given in the Introduction. Numerous Upper Carboniferous fossils were obtained from the late Mr. John Aitken. A series of specimens from the Palæozoic formations of Bohemia was purchased from M. Barrande in 1856. The collection of Mr. J. H. Burrows, purchased in 1872, comprises Mollusca and Brachiopoda from the Carboniferous Limestone of Settle. The De Stefani collection of Italian Pliocene fossils was purchased in 1882; and a fine series of British Pliocene fossils, with others from the Cretaceous and Upper Jurassic, formed by Mr. Montagu Smith, was presented in 1883. Mr. Kinsey Dover presented his cabinet of Trilobites and Graptolites from the Skiddaw Slates in 1890; and the Rev. O. Fisher has long been a generous donor to the Museum in many departments. Other donations are the Forbes-Young collection of Chalk fossils, the Goodman collection of Tertiary fossils, and the Walton collection of British Jurassic fossils. The series of Corals, Trilobites, etc., from the Wenlock Limestone, collected by Captain T. W. Fletcher; the Cretaceous collection of the Rev. T. Magee; and the large collection of Mr. John Leckenby, from the Jurassic and Cretaceous of Yorkshire, are other important purchases. Many fossils, chiefly Mollusca and Brachiopoda, from the Inferior Oolite of Somerset and Dorset, were purchased from Mr. H. Monk in 1885; and the large and varied collection of the late Mr. H. E. Strickland was bequeathed in 1888. By the purchase of part of Count Münster's collection in 1840, the Museum acquired a large series of Triassic and Jurassic fossils from the Continent; while the donation of part of Mr. J. Hawkins' collection of Saurians from the Lias in 1856, and the purchase of Dr. H. Porter's collection of Saurians from the Oxford Clay of Peterborough in 1866, made important additions to the series of fossil Vertebrata in the Museum. Local fossils have been obtained by innumerable donations and purchases.

The genera and species in the Catalogue are arranged in alphabetical order under their respective classes, and cross-references are given to the synonyms introduced. The list everywhere bears evidence of most careful preparation, and the typography is well arranged for convenience of reference. When so much labour and care have been bestowed, it may appear ungracious to criticize; but we must express the opinion that if Mr. Woods had clearly dis-

tinguished between "types" and those specimens merely noticed or figured, his work would have been of much greater use. Moreover, personal expressions of opinion, which may be right or may be wrong, seem quite out of place in a list of this kind, which ought to be nothing more than an index to the *origin* of certain names that have been used in Systematic Palæontology.

REPORTS AND PROCEEDINGS.

Geological Society of London.

I.—March 23rd, 1892.—W. H. Hudleston, Esq., M.A., F.R.S., President, in the Chair.—The following communications were read:

1. "On the Occurrence of the so-called *Viverra Hastingsiæ* of Hordwell in the French Phosphorites." By R. Lydekker, Esq., B.A., F.G.S.

The author shows that *Viverra Hastingsiæ*, Davies, is common to the Oligocene of France and Hordwell, and finding that there is no character by which the lower jaw of the type of the latter can be satisfactorily distinguished from the type of *V. angustidens*, Filhol, he considers that *V. Hastingsiæ* is specifically inseparable from *V. angustidens*, and figures the cranium which is the subject of the communication under the latter and earlier name.

He gives a list of seven mammals known to be common to the Headon beds of Hordwell and the Isle of Wight, and the French Phosphorites.

2. "Note on two Dinosaurian Foot-bones from the Wealden." By R. Lydekker, Esq., B.A., F.G.S.

In this paper the third right metapodial (metacarpal?) and an associated phalangeal of a Sauropodous Dinosaur, obtained by Mr. C. Dawson from the bone-bed of the Wadhurst Clay, are described, and referred with doubt to *Morosaurus*.

The author also discusses the relationship of *Acanthopholis platypus* from the Cambridge Greensand.

3. "On the Microscopic Structure, and residues insoluble in Hydrochloric Acid, in the Devonian Limestone of South Devon." By Edw. Wethered, Esq., F.G.S., F.C.S., F.R.M.S.

Microscopic examination of the Devonian Limestones of South Devon shows that they have been built up by calcareous organisms, but that the outlines of the structure have for the most part become obliterated by molecular changes, and the limestones are often rendered crystalline. In connexion with this the author alludes to the disturbances which have affected the limestones. He finds occasional rhombohedra of dolomite, and discusses the probability of their derivation from magnesian silicates contained in the rocks.

A description of the insoluble residues follows. The micas, the author considers, may be of detrital origin, but this is by no means certain; he is disposed to consider that the zircons, tourmaline, and ordinary rutile were liberated by the decomposition of crystals in

which they were originally included. Minute crystals, referred to as 'microlithic needles,' resemble 'clay-slate needles,' but are not always straight: they occur in every fine residue, and as inclusions in siliceous and micaceous flakes. The siliceous fragments which enclose them frequently contain many liquid inclusions, which does not necessarily imply any connexion between the two, though there may possibly be some connexion. Micro-crystals of quartz occur, and have been derived from decomposing silicates.

II.—April 6, 1892.—W. H. Hudleston, Esq., M.A., F.R.S., President, in the Chair.—The following communications were read:

1. "Geology of the Gold-bearing Rocks of the Southern Transvaal." By Walcot Gibson, Esq., F.G.S.

The author describes the general characteristics of the rocks of the Southern Transvaal, and gives a summary of previous work on the area; he then discusses the physical relations of the gold-bearing conglomerates and associated rocks in the Witwatersrandt district, and describes the various rocks in detail.

He concludes that the gold-bearing conglomerates and the quartzites and shales of the Witwatersrandt district (which have undergone considerable metamorphism) form one series, of which the base and summit are not seen; that this series is much newer than the gneisses and granites on the eroded edges of which they rest, and older than the coal-bearing beds which unconformably overlie them; that the entire series associated with the gold-bearing beds has been thrust over the gneisses, and was not originally deposited in its present position, the movements having taken place in two directions, viz. from south to north and from east to west; that, after the cessation of these movements, the strata were injected with basic and sub-basic igneous material, and much of the country was flooded with lavas of the same character; and that the conglomerates have been formed mainly at the expense of the underlying granites, and gneisses which were largely threaded with auriferous quartz-veins and contained larger masses of quartz.

The author then describes the geology of districts outside the typical area, which, though at first sight more complex, are really simpler than that of the typical area. The conclusions arrived at from an examination of these areas confirm the results of the study of the rocks of the Witwatersrandt district.

2. "The Precipitation and Deposition of Sea-borne Sediment." By R. G. Mackley Browne, Esq., F.G.S.

The author discusses the mode of deposition of current-borne sediment upon the ocean-floors, and considers the effects of current-action in sifting the material and causing it to accumulate into stratified linear ridges having directions generally parallel with those of the currents—the dip of the strata varying according to the velocity of the currents. He considers that the conclusions deducible from his analysis appear to be in accord with the evidence afforded by the structure of ancient subaqueous sedimentary deposits.

CORRESPONDENCE.

ARCHÆAN LIMESTONES ON THE FLANK OF THE MALVERN RANGE.

Sir,—The works which have been in progress for some weeks for the new reservoir of the Great Malvern Waterworks on the north-east flank of the Hereford Beacon have already brought to light a fact of no inconsiderable importance in its bearing upon the geology of this most interesting region. Briefly it may be described as follows:—The reservoir is to be formed by a huge dam to be constructed across the deep valley which runs down from the north-eastern flank of the Beacon, between the two most northerly of the four spurs or buttresses which most geological writers on the district have noticed abutting upon the Triassic plain of the Severn. It is in the deep wide trench which has been excavated for the foundations of this dam that the limestone is best exposed. The rock is a compact crystalline limestone, with a more or less distinct bedding, though much jointed in all directions, as if by incipient crushing, probably somewhat dolomitic, of a light-grey colour on fresh fractures, but in the more decomposed portions stained with oxides of the heavier metals; secondary crystals of calcite are often formed in quantity on the divisional planes of the rock.

Of *the age of the rock* (which so far appears to be absolutely unfossiliferous) there cannot be very much doubt. As the field-relations show that it cannot be younger than the complex of lavas and altered tuffs and volcanic muds of the hills between which the valley lies, a complex of rocks which two of the most capable judges on this question (Drs. Callaway and Hicks) refer to the Pebidian (later Archæan). My first visit to the spot was in company with Dr. Callaway, about a week ago; and the suggestion that the rock is one "archæan limestone of chemical origin" was made by him. On a second visit yesterday with my friend Mr. H. D. Acland, of Malvern, I was able to follow the exposition which the foreman of the works gave of its position in relation to what he called the "whin-rock." It strikes nearly north-west, and dips at an angle of about 80°. It alternates with the "whin-rock," which seems related to it as an "interbedded trap" (as if the two rocks were contemporaneous portions of the Pebidian series of this locality), or possibly, from the fact stated to us that the limestone is "softer and easier to work against the "whin" (as if the latter were intrusive), even somewhat older than the volcanic series. Macroscopic examination of some specimens seemed, however, to indicate contemporaneity by the apparent presence of pyroclastic materials in some portions of the limestone.

The presence of limestones (even massive limestones) in the later Archæans is known; and until quite recently it was generally assumed in this country that they illustrate those extreme views of "regional metamorphism" so much in vogue, the metamorphism having been so complete in such cases as to have obliterated all traces of organic remains. In 1888 I challenged that view, on the

ground of the much greater probability of a directly *mineral origin* of such limestones, as the necessary result of chemical reactions, which a common-sense application of known laws of thermal and general chemistry tells us must have taken place in the earlier ("pre-oceanic") stage of the history of our earth. This was put plainly enough before the geological world in my "Metamorphism of Rocks" (Longmans, 1889), pages 6–16; and it is needless that I should do more now than refer the reader to that work, so far as concerns the theoretical bearings of the facts here narrated.

MALVERN. A. IRVING.
13*th April*, 1892.

REPLY TO PROF. J. F. BLAKE.

SIR,—There is only one point in Prof. Blake's reply in your April Number that I intend to notice. Prof. Blake writes:—"General McMahon says he was considering capillary flow under heat and *pressure*, but in his paper he really only discusses the action of heat, and the present discussion on the effect of pressure is a new one." This statement is really a very extraordinary one. In my paper in the GEOLOGICAL MAGAZINE (February, 1892, pp. 74, 75), I simply refer to statements regarding pressure made in my original paper (Proc. Geol. Assoc. vol. xi. pp. 431, 432). In this last paper I showed that pressure was a very important factor, and I gave very interesting statistics at pp. 438, 439 (then published for the first time) supplied to me by an eminent engineer showing that in the case stated, the actual measured pressure at 190 feet below the surface, was equal to the calculated pressure, and was no less than 80 lbs. on the square inch.

I do hope for the future success of "The Annals of British Geology," that Prof. Blake will devote a little more attention to the mastery of the papers he attempts to boil down. Unless he does so, I am afraid that his geological Bovril will not prove a very stimulating or nourishing article.

20, NEVERN SQUARE, C. A. MCMAHON, Major-General.
10*th April*, 1892.

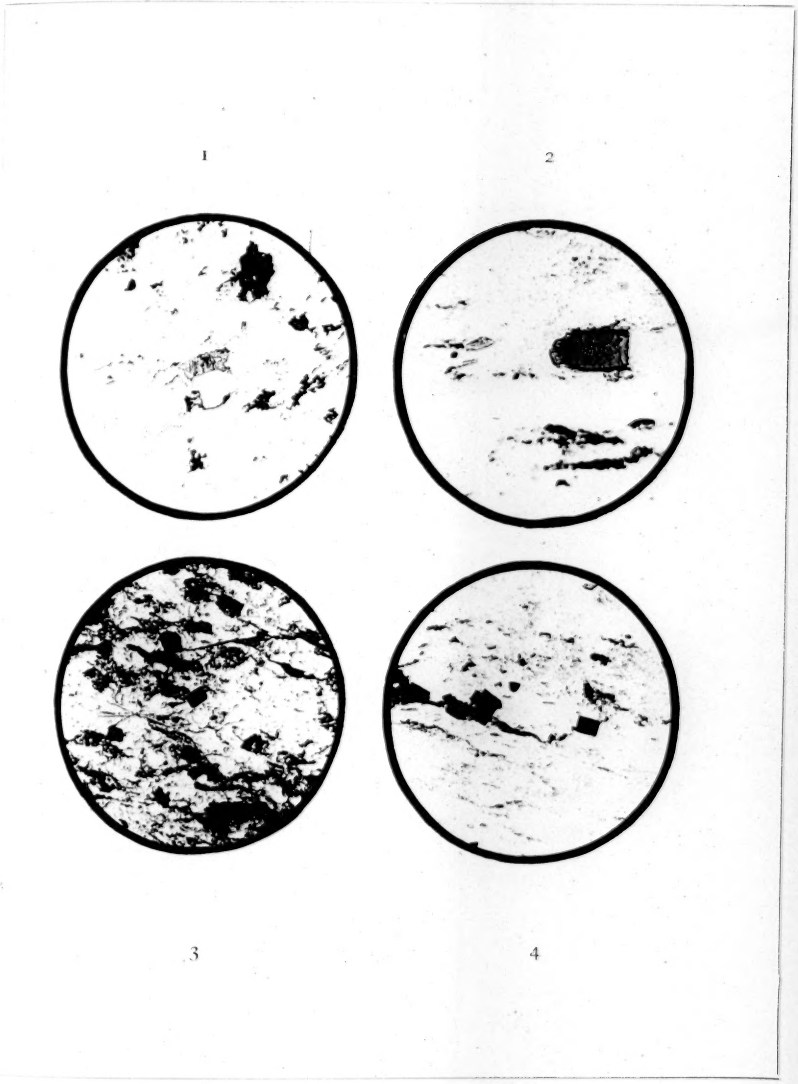
CONE-IN-CONE STRUCTURE.

SIR,—If Mr. Young's statement[1] is meant to be of universal application, it is certainly not borne out by observation. A radial arrangement of the cones about a large nodule is, I believe, not an uncommon thing. Good examples occur in the Lingula Flags of Borth near Portmadoc, which contain flattened nodules, extending along the bedding, sometimes several feet long. Each is surrounded by a layer of well-characterized "cone-in-cone," and the apices of the cones are directed inwards towards the nodule, so that they point downward on the upper side, upward on the lower side, and horizontally on the edges of the nodule. I have noticed the same thing on a smaller scale in the shales of the Yorkshire Lias.

ST. JOHN'S COLL. CAMB. ALFRED HARKER.

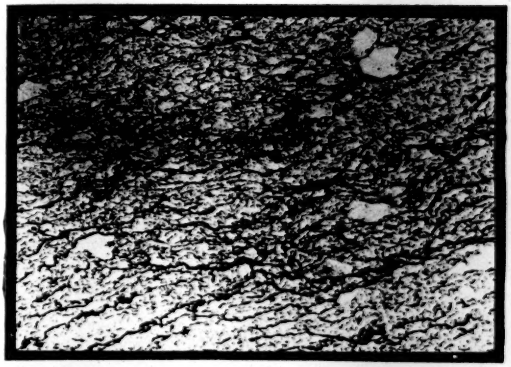
*** The Editor regrets that, through inadvertence, this letter has been delayed in publication.—EDIT. GEOL. MAG.

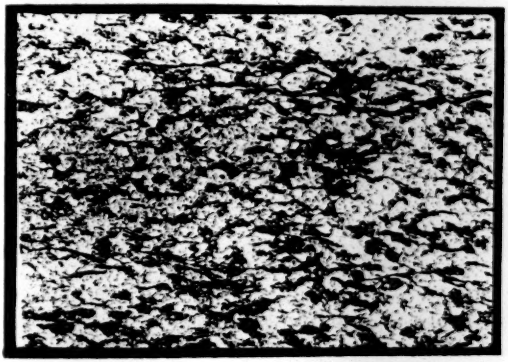
[1] See GEOL. MAG. for March last, p. 138.



To illustrate Mr. Hunt's Paper on the Rocks of South Devon.

1





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To illustrate Mr. Hunt's Paper on the Rocks of South Devon.